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ECONOMIC GEOGRAPHY

APRIL

ALUMINUM INDUSTRY OF EUROPE
James E. Collier

TURNING OF TIRNOVO
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ROLE OF PUEBLO INDIAN ECONOMY IN SANTA FE
Irene A. Moke

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ALUMINUM

IN less than half a century aluminum has become one of the world's most valued and useful metals. For a long time it resisted man's effort to extract it from its ores readily and cheaply. Chemical and other technological skills failed to yield the secret of its easy and economic winning and working. Metal aluminum was hard to produce, costly, and rare only a few decades ago, whereas it has now become abundant, is inexpensively obtained, and plays an important part in man's metallurgy, economy, and industrial progress.

The drama of reducing aluminum from one of the refractory, expensively wrought metals to its present position as a metal for widespread multiplicity of uses in man's equipment and material culture forms a brilliant episode in the saga of his cultural progress. Deliberately, ingeniously, successfully he won from the raw ore, bauxite, the light malleable and flexible metal he so sorely needed to fly, to float, and to work more easily than ever before.

The whole world is now conscious of advantages aluminum provides for the arts, and for industries by which man improves his standards of living. Ores from which aluminum may be won are carefully being studied and investigated for their potentialities for production of the metal. Whereas bauxite as the principal ore at present, and cryolite as the most important flux, enter most significantly into the aluminum industry of the period, other ores may in time displace them, or new methods may make their use even more important. It may well be that other metals, like magnesium, even more spectacular for their levity, will play a larger part in man's metallurgy of the future than aluminum does today, or bids fair to play tomorrow.

ECONOMIC GEOGRAPHY

VOL. 22 APRIL, 1946 No. 2

ALUMINUM INDUSTRY OF EUROPE

James E. Collier

ALUMINUM has been one of the critical materials of the present war and one of the major industrial metals of modern times. Possession or control of a reliable source of aluminum is important in the military and industrial strength of any modern nation.

Production of aluminum in Europe before the war involved use of raw materials, fuel and power produced in several different countries. No one country possessed all requisite elements for its manufacture, well located with respect to one another. During the years of war many changes took place. Little information is available regarding details of the modifications in the industry, although definite trends were evident during the preceding years. The postwar situation will no doubt differ from both prewar and wartime conditions. However, analysis of known facts serves to determine geographic conditions which are pertinent to the industry and throw some light on the probable situation of the future.

Major activities involved in production of aluminum are threefold: (1) mining bauxite, the principal ore, (2) thermochemical removal of nonaluminous materials from ore, producing alumina, and (3) electrolytic reduction to metallic aluminum. Basic economic-geographic factors which apply to each stage of the process largely affect its location and distribution.

BAUXITE RESOURCES AND PRODUCTION

Almost half the known bauxite resources of the world are in Europe. Aggregate reserves total more than a half-billion tons. At the average annual rate of two million tons consumed during the decade from 1930 to 1939, the deposits could supply the world's bauxite requirements for more than two and one-half centuries. Hungary alone is reported to have 250 million metric tons of usable ore, the largest known reserves of any country. Yugoslavia is estimated to have 100 million tons, and France and Greece each have approximately 60 million tons. Romania has 40 million tons, Italy 20 million tons. Norwegian-controlled Jan Mayen in the Arctic Ocean is reported to have 30 million tons, and in the U.S.S.R. about 20 million tons have been proven (Figure 1).

Distribution of bauxite production in Europe is somewhat different from distribution of the apparent reserves. Leading producers during the five-year period from 1934 to 1938 were France, Hungary, Yugoslavia, Italy, Soviet Union and Greece (Figure 2). Although third or fourth in order of reserves, France is the leading bauxite mining country,

accounting for one-third the total production during the period and for almost twice as much as her nearest competitor. Average annual production during the above period was 612 thousand metric tons. Hungary ranked second with 360 thousand tons annually.

France not only occupies the leading position among European bauxite producers, but also among world producers.

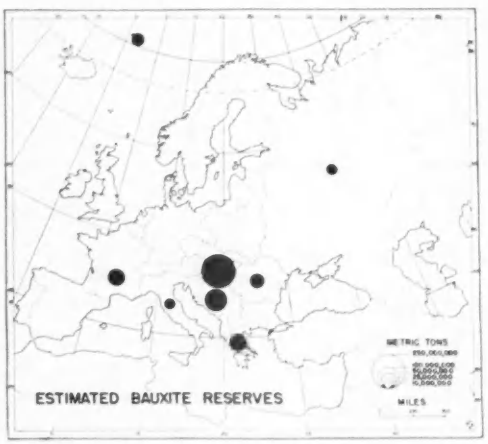

FIGURE 1.—Distribution of bauxite reserves of Europe. (Data from Minerals Yearbook and other sources.)

During the decade ending in 1939, average tonnage mined in France was more than twice as great as any other country and was almost one-fourth the world's total (Figure 3). The average was 584,600 metric tons, as compared to an average of 269,000 tons for the United States and 267,000 for Hungary, respectively second and third in rank. Other principal producers included Surinam, British Guiana, Netherland Indies and Malaya, in addition to the European countries listed above.

FRANCE

The principal bauxite deposits of France are near the Mediterranean coast in the departments of Var and Herault. More than three-fourths of the total production in recent years has been from the Var district and three-fourths of the remainder from the Herault district. Minor deposits are in the department of Bouches du Rhone, also on the Mediterranean coast, and in Ariege on the northern slopes of the Pyrenees Mountains. The more important mines in the Var district are in the Brignoles region north of the port of Toulon (Figure 4). In 1937, twenty-six mines in Var produced 552,900 tons of bauxite; five mines in Herault produced 107,000 tons; three mines in Bouches du Rhone produced 24,000 tons; and two mines in Ariege produced 4,300 tons, according to the September 1938 issue of *Foreign Minerals Quarterly*, U. S. Bureau of Mines.

Since the original development of the aluminum industry, France has consistently been the leading bauxite producing nation of the world, except for a short period during and immediately following the first World War when United States production was greater. Fluctuations in production have accompanied European and world economic changes. A relatively regular increase marked the production trend during the first dozen years of the century (Figure 5). From the first major peak of 304,000 tons reached in 1913, production dropped as a result of the war to 106,000 tons in 1916. Except for a slump to 95,000 tons in 1921, the output increased afterward and reached a second major peak in 1929, when 666,000 metric tons were produced. After dropping to approximately 400,000 tons in 1931 and 1932, production gradually rose to 688,000 tons in 1938 and remained at approximately that amount to the outbreak of the war.

Slightly more than one-half of the French bauxite is consumed in France and the remainder exported, either as crude or dried ore, or as refined ore

(alumina). Some 16 per cent of the domestic consumption is used for the manufacture of cement, refractories, abrasives, and other products, while the remainder is used for the manufacture of metallic aluminum. During the five-year period from 1934 to 1938, exports were about 48 per cent of the total production. An average of 173,000 tons of bauxite were exported annually to Great Britain during this period and 85,000 tons to Germany. In 1935 France, for political and war-economic reasons, placed bauxite exports under license and restricted exports to Germany to 15 per cent of the total. This reduced by one-half the German imports from France. Sweden, the Netherlands and others received a total of approximately 34,000 tons annually. Alumina exports averaged about 32,000 tons and were shipped chiefly to Switzerland and Norway. Both bauxite and alumina were exported via the Mediterranean ports of Marseille, Toulon, St. Raphael, Port de Baux, and Cette. The special quality of French bauxite which partially accounts for its demand by several importing countries is partly the natural richness of the ore and in part careful selection and grading of the ore after it is mined. In addition the cost of exporting from fields near the coast is low.

HUNGARY

The bauxite deposits of Hungary contain in three districts estimated reserves of more than 250 million metric tons, the largest known reserves of any country. The most important of these districts at the present is the Bakony Forest and Vertes Mountain area of northwestern Hungary (Figure 6). A second region in which high grade bauxite occurs is in southern Hungary near the Yugoslavia boundary. In eastern Hungary is the bauxite region of the Bihar Mountains which extends into Romania.

Most of the bauxite production of Hungary has been from the vicinity of Gant in the Vertes Mountains north of Lake Balaton. These deposits have been estimated by Q. D. Singewald to contain 120 million tons of high-grade ore. Until recently this has been the only region of Hungary in which extensive mining was carried on. Mining is chiefly by open-cut methods. The deposits are soft so that operations are by hand and at low cost. The bauxite now being mined lies in depressions between dipping, faulted blocks. The increasingly deeper and thicker sediments overlying the ore preserved on some of these tilted blocks prevents profitable mining by surface methods. Some of the ore bodies of this district are associated with limestone pockets and lenses. As exploitation progresses

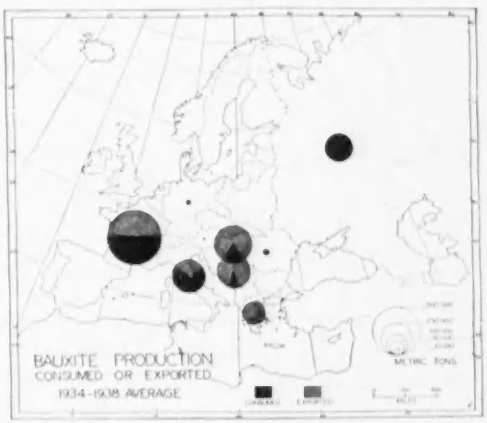

FIGURE 2.—Bauxite production in Europe, 1934–1938 average. (Data from Minerals Yearbook and other sources.)

more and more of the mines will become the shaft-tunnel type and the cost of production correspondingly increased.

The Bakony Forest area near Halimba contains even greater reserves than the Vertes Mountain region, the estimate being 130 million tons, according to U. S. Dept. Commerce, *Foreign Com-*

merce Weekly, July 25, 1942, p. 26. The resources had not been developed up to the outbreak of war, however, and production was insignificant. The ore is relatively low-grade and, since the heavy overburden requires underground methods, mining costs are greater than in the Vertes Mountain region.

The second region in which high-grade bauxite is found lies in the Baranya area of southern Hungary near the Yugoslav boundary. The reserves are small, being estimated at 200,000 tons. Most of the ore bodies are lenticular deposits or pockets and must be mined by the more expensive underground methods, although limited operations by open-pit methods are possible in some parts of the district. Annual production approximates 5,000 tons.

In eastern Hungary and extending into Romania is the bauxite region of the Bihar Mountains. Hungary's deposits here are estimated to contain 10 million tons of ore in sight and a total of possibly twice as much. No mining had occurred in this district in 1939.

Hungary's bauxite mining industry originated during 1925 and experienced a remarkable expansion to an output of 396,000 metric tons in 1928 (Figure 5). Production dropped to 32,000 tons in 1930, followed by a slow recovery. The conditions of approaching war and the expansion of aluminum production in Europe, particularly in Germany, resulted in more than doubling the output from 1935 to 1937. Restriction of Germany's imports from France at that time resulted in larger German purchases of Hungarian bauxite. The annual production from 1937 to 1940 was between 530,000 and 570,000 tons.

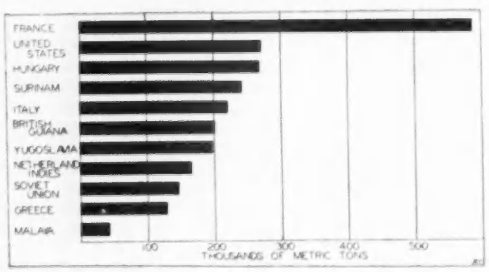

FIGURE 3.—Bauxite output of the leading producing countries, 1930–1939 average, except Netherlands Indies (1935–39), Soviet Union (1931–39), Greece (1935–39), Malaya (1936–39). (Data from Minerals Yearbook and Mineral Industry.)

Most of Hungary's bauxite has been exported to Germany. The establishment of an aluminum industry in Hungary has resulted in a domestic consumption of approximately 50,000 tons of bauxite annually since 1935. However, this is a very small part of the total output. The low mining costs and favorable transportation conditions make Hungary the logical source of bauxite for the German aluminum industry. Similarly, Germany is the most convenient and economical market for Hungarian bauxite. Bauxite from the Gant mine is shipped by the mining company's narrow gauge railroad to the main line at Bodajk. From this point the ore may be shipped by rail to the German alumina plant near Leipzig or it may be shipped by rail to the Danube River port of Komarom and thence by water to the new Schwandorf plant in Germany. The cost of ore shipped to Leipzig is more than twice that shipped up the Danube to Schwandorf, as stated in U. S. Bureau of Mines, *Foreign Minerals Quarterly*, January, 1938, p. 83.

YUGOSLAVIA

Yugoslavia has extensive deposits of bauxite, with workable reserves estimated at 100 million tons. Most of the known occurrences are near the Adriatic coast and on some of the coastal islands (Figure 7). Inland deposits are less well known and their exploitation more difficult and expensive. Most of the deposits are associated with the region of karst topography, occurring as layers, lenses or pockets in the soluble limestone

which is common in the area. Many of them outcrop at the surface, with little or no soil covering, according to Junius D. Edwards, Francis C. Frary and Zay Jeffries, in *Aluminum and Its Production*, McGraw-Hill, 1930, p. 112.

The original development of Yugoslavian bauxite began during the first World War with the German and Austrian attempts to find a substitute for French ore which they had been importing. More recent production has been largely for the export market, with small annual tonnages to meet the limited but growing requirements of the domestic aluminum reduction industry. The major production has been from the Dalmatian region at locations accessible from the coast. More than three-fourths of the 1938 production came from this region. Mining has centered around Drnis and south of Knin. This district is connected by railroad with the ports of Split and Sibenik, from which the ore destined for export is shipped (Figure 7). Ore for the aluminum manufacturing plant near Sibenik is also supplied by this bauxite district. The most important production to date has been from the Kalun deposits of this district. Most of the rich surficial deposits which had accumulated in sinks and dolines in the soluble limestones have been mined and underground methods are now necessary to reach the deeper deposits. The ore is the red, high-iron type and is of relatively high grade. In addition to the Drnis district, the Sinj district northeast of the port of Split and connected with that port by means of a railroad is a major producing area. Near Imotski, east of Split and some 20 miles inland, are large and little known deposits which have only recently been worked. These extend northward and eastward as far as the provinces of Vrbaska and Drinska (Figure 7). Because of the railway haul to Mostar and to the coast, the cost on board ship is higher than that of the Drnis district, but this is compensated by the higher selling price.

The bauxite occurrences of the Adriatic coastal region extend into southern and western Savska, where extensive occurrences have not yet been developed. The most attractive of these seem to be those in the vicinity of Gracac, northeast of the southern end of the Velebit Mountains which parallel the Adriatic coast. There are estimated to be more than a million tons of ore in this district, but the region is somewhat isolated and handicapped by a lack of adequate transportation facilities. The most direct outlet would be westward over the Velebit Mountains to the coast. The easier outlet is by rail southwestward to Knin and thence southwestward through Drnis to Sibenik or Split. This latter outlet by existing rail connections would mean transporting the bauxite through the already developed districts of Knin and Drnis, and the more isolated district would be handicapped by the longer rail haul.

The bauxite of southeastern Primorska lies in the lower valley of the Neretva River, centering in the vicinity of Mostar. The ore is reported to be of a good grade. It is the high-iron type, but contains up to 72 per cent alumina. Mining has been confined to a small area in the Siroki Brijeg mountains west of Mostar, but the district produced almost one-fourth of the total Yugoslavian output in 1938. Deposits occur elsewhere in the district and are definitely known in the vicinity of Xitomislic, about 12 miles south of Mostar. Not all of the large deposits of this district have been surveyed. Estimates of the known reserves indicate about five million tons. Swiss commercial interests are reported to

have been instrumental in the development of the bauxite mines of this region and plans for the construction of an aluminum reduction unit near Mostar by a German concern were reported in 1938.

Bauxite deposits, apparently of high quality, are present in southern Zetska

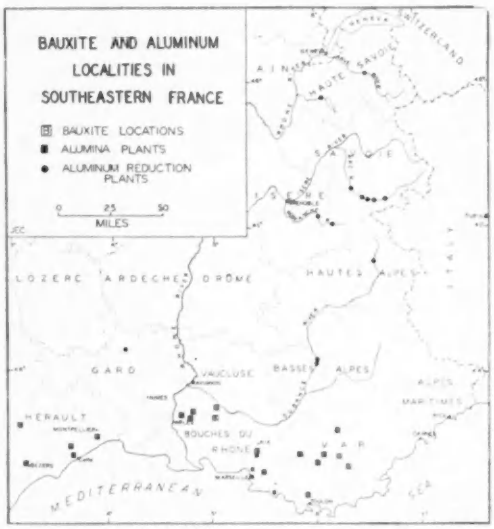

FIGURE 4.—Bauxite localities and alumina and aluminum plants of southeastern France.

between Lake Scutari and the coast, and extend northward up the Zeta River valley as far as Niksic (Figure 7). A deposit of some importance lies just west of Niksic. A large deposit of 30 million tons of bauxite lies between Bar and Ulcinj in the district south of Lake Scutari. The deposits of the Niksic district have not been developed because of their distance from the sea and the inadequacy of transportation facilities, but there is no apparent handicap to the development of those south of Lake Scutari, since they are of good quality and are not more than five or six miles from the sea. A railroad runs inland from Bar to the northwestern end of Lake Scutari, passing near if not through this district.

There are numerous bauxite deposits in northwestern Yugoslavia. The ore of the Wochein and Feistritz region in the headwaters of the Sava River has been known since 1886 and is practically exhausted. Farther east, the occurrences of the Steiner Alpen and the Celji region in the Sann River valley are relatively recent discoveries. There are also deposits elsewhere in the Upper Sava valley and on the northern Adriatic islands of Rab, Krk and Cherso. Many of these deposits in the northwestern parts of the country are not at present considered to be of commercial value because of their poor quality and the difficulties of transportation.

Production of bauxite in Yugoslavia before 1925 did not exceed 100,000 tons per year (Figure 5). It fluctuated around that amount until 1935, when for the first time more than 200,000 tons were mined. The output rose to 400,000 tons in 1938 and declined to an estimated 260,000 tons in 1940.

Most of Yugoslavia's bauxite is exported. The limited amount of aluminum produced in the country required only 16 per cent of the average annual bauxite production from 1930 to 1939 (197,879 tons) and the remainder was exported, chiefly to other European countries. Germany took 96 per cent (160,000 metric tons) of these exports, and small quantities were shipped to Italy, Sweden and the United States. Shipment is normally by water from the ports of Split or Sibenik to Netherlands or German North Sea ports for transhipment to reduction centers in the Rhine and Elbe River valleys, since most of the land routes are not good and are relatively expensive.

ITALY

Numerous occurrences of bauxite of varying grade and size are known in Italy. Mining has been carried on mainly in two regions: in the peninsula

of Istria, and in the south central Apennine provinces of Abruzzi and Campania. The Istrian deposits are more important, both with respect to quantity and quality of the bauxite. Recent estimates place the total reserves at about 34 million tons, although two-thirds of this is high in silica and not suitable for the Bayer alumina process. Certain bauxite bearing areas of the country have not been fully explored, however, and the total resources may ultimately prove to be much greater than this estimate. In addition, recent improvements in processing high-silica bauxite may extend the usable reserves.

The Istrian deposits occur in three groups in a north-south zone through the center of the province (Figure 7). The most important of these is in the central part of the peninsula. Istrian reserves have been estimated at approximately 16 million metric tons of usable ore. Five or six million tons have been added to the known resources by the recent discoveries in the vicinity of Aidussina in this central district. Other occurrences are in the southeastern portions of Istria and on adjacent islands. A third district, a continuation of adjacent Yugoslavian deposits, is in the Isanzo River valley and on the slopes of the Julian Alps in northern Istria. The bauxite of Istria as a whole is similar in character and modes of occurrence to that of the Dalmatian region. Approximately 60 mining concessions are held in Istria, although the maximum number of locations worked at any one time in recent years has been about twenty.

The bauxite of peninsular Italy occurs on both sides of the central Apennines and in southern Italy. Before the annexation of Istria, this area was the chief source of ore. The deposits of the provinces of Abruzzi and Campania are of greatest value, although recent discoveries have extended the known resources of the province of Apulia on the Adriatic side of the peninsula. Ore from Abruzzi was used in the first aluminum reduction plant constructed in Italy. The reserves of Abruzzi and Campania have been estimated at 6 million tons and 2½ million tons, respectively. The Apulian deposits are estimated to contain 4½ million tons of usable ore.

The annual production of bauxite from peninsular Italy has not been great. The deposits of the Bruzzi Mountains and the vicinity of Benevento in Campania have been known for more than a quarter of a century, but because of the high iron content of the ore, they have been worked only on a moderate scale. The aluminum producers prefer the better grade Istrian ore. The annual production of the Apennine district has generally been less than 20,000 tons. The more recently discovered Apulian deposits near the Gulf of Manfredonia are becoming of considerable importance for aluminum production. Mining began in 1939 near San Giovanni, about 20 miles north of Foggia, and the ore is also produced in other parts of this district. The bauxite is shipped from the port of Manfredonia to Venice for use in northern Italian plants.

Italy's bauxite production began on a small scale in 1905, but remained less than 10,000 tons annually until after the first World War and the acquisition of Istria. During the war years Istria was producing from 50,000 to 70,000 tons. This total Italian output declined with the close of the war. The production rose steadily from 13,000 tons in 1920 to 140,000 tons in 1924 and almost 200,000 tons in 1925, but dropped to 5,000 tons in 1926, recovering slowly to another production peak of 193,000 tons at the beginning of the world-wide

depression following 1929. Through another period of slow recovery Italy reached an output of 170,000 tons in 1935, 262,000 tons in 1936, and 386,000 tons in 1937. The output dropped slightly in 1938, but rose to an all-time record of 484,000 tons in 1939 (Figure 5). Except for short periods, Italy has ranked third among European and fifth among world producers of bauxite (Figure 3).

Since its acquisition by Italy, Istria has supplied approximately three-fourths of Italy's total bauxite production, with the other deposits apparently being held partly in reserve. The proportion of Istrian ore used for aluminum production is even greater than this, since the bauxite of Campania is used chiefly for the manufacture of aluminum salts and artificial corundum. The recently discovered Apulian deposits near Foggia are used in the manufacture of aluminum and the output was increasing during 1940 and 1941.

Italy is one of the few bauxite-producing countries which also has an important aluminum industry, and most of the production is used domestically. Approximately one-third of the prewar output was exported, almost all of it to Germany. Exports have been declining, however, and in 1938 only one-fifth of the total output was exported. Limited amounts of refined bauxite (alumina) have been shipped to Switzerland.

SOVIET UNION

The known bauxite resources of the Soviet Union, until a few years ago, were meager and of poor quality. Until 1935, only the low-grade deposits of the Tikhvin district, east of Leningrad, were being mined as ore for aluminum reduction. Within the last decade, however, intensive exploration has led to the discovery of several new bauxite districts which greatly extend the reserves and which have resulted in a phenomenal

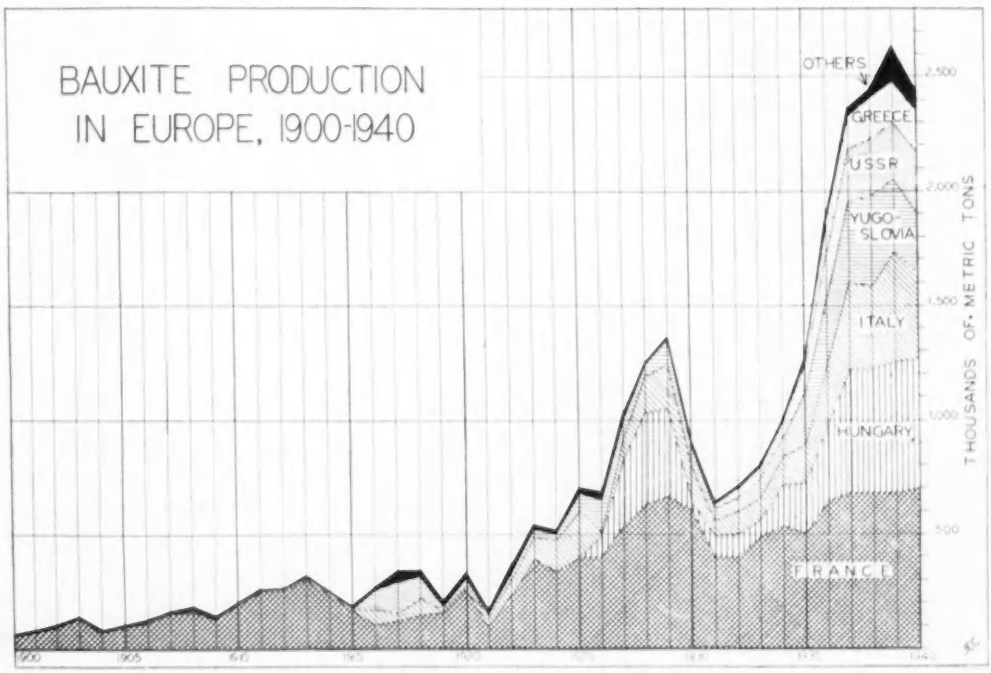

FIGURE 5.—Bauxite production in Europe, 1900–1940 (1940 figures estimated). (Data from Minerals Yearbook and other sources.)

growth of aluminum production. With the development of new deposits, the bauxite output rose from 11,600 metric tons in 1931 to 203,000 tons in 1936, and to an estimated 270,000 tons in 1940.

Most of the usable bauxite deposits of the U.S.S.R. are in the Ural Mountain region. The better ore of the Tikhvin district has already been mined and the remaining part of the originally estimated 8 million tons of ore is for the most part low-grade. Because of the excessive silica content of Tikhvin ore, the cost of aluminum has been considerably higher than the world market price and this, together with the limited reserves of the district, led to the extensive search which brought to light the new deposits now supplying most of the bauxite consumed in the Soviet Union.

Probably the most valuable of the bauxite districts of the Urals is the Kabakovsk district on the eastern slopes of the Central Urals (Figure 8). Because of its high quality and uniform composition the Krasnaya Shapochka deposit in this district is estimated to be one of the best in the world. This deposit contains at least 10 million tons of ore and the total reserves of the Kabakovsk district are estimated at 30 million tons. South of the Kabakovsk district is the Kamensk district. Two deposits in this district contain 11 million tons of bauxite and their favorable location has led to the establishment of an aluminum reduction industry at Kamensk. The Kamensk alumina and the aluminum plants use bauxite from the Kabakovsk district as well as local ore. On the western slopes of the southern Urals are the Satinski and Katav-Ivanovski districts which contain more than 5 million tons of usable ore. About 100,000 tons of bauxite were mined from these two districts in 1937. In the southern Urals bauxite occurs in at least two other districts, and although figures of reserves have not been issued, the total amount is thought to be large.

Bauxite occurrences have been reported at a number of places in the Kazak republic, and in Uzbek S.S.R. Several deposits in the Akmolinsk district seem to be the most important in the former area, and a large deposit situated north of Andizhan in Uzbek is indicated to be of satisfactory quality. Other occurrences in the Soviet Union are in the Kirghiz republic, in West Siberia, East Siberia and in the Far Eastern Territory, but most of these deposits have not been fully studied and the reserves and industrial value remain undetermined.

In her search for aluminum ore and in the absence of sufficient favorably located bauxite deposits, the Soviet Union has turned in part to non-bauxite sources of aluminum. Recently there was begun operations for the extraction of aluminum from nepheline syenite tailings of apatite mines in the Kola Peninsula. A specially developed, new and simplified process permits the production of aluminum, with potash and phosphoric acid as by-products. An attempt has also been made by the Soviet Union to derive aluminum from alunite. Estimates indicate that there are approximately 93 million tons of alunite in U.S.S.R., mostly in the Caucasian area, from which some 10 million tons of aluminum can be produced.

GREECE

Deposits of bauxite are fairly widespread in the limestone regions of southern and western Greece, with similar occurrences on many of the islands in the Aegean Sea, including Amorgos, Naxos, Melos, Kimolos and Seriphos of the Cyclades group, and Aegina in the Gulf of Aegina. The most impor-

tant deposits at present are those just north and east of the Gulf of Corinth, particularly on the southern slopes of Mount Parnassus. These and the deposits on the island of Amorgos were the only deposits being mined in 1940. Total reserves have been estimated at 60 million tons, although subsequent exploration may extend the known occurrences of commercial quality ore. Approximately 10 million tons are available in the area of recent mining operations. The ore is of relatively good quality and occurs as layers or pockets in limestone. Mining is still by open pit methods and the ore is shipped from Parnassus by rail to the small harbor of Itea for export. The proximity of the developed areas to coastal water, together with the low cost of surface mining, enables low-cost production ($1.04 to $1.06 per long ton, delivered at the dock) and export to foreign markets. The cost of mining will increase as underground mining becomes necessary and as the more conveniently located deposits are exhausted.

The annual production of bauxite in Greece prior to 1935 was less than 15,000 tons. During 1936 15,000 tons were mined, while the output in 1938 and 1939 approached 200,000 tons. The greater demand and increase in price in world markets was a natural cause for this greatly increased production.

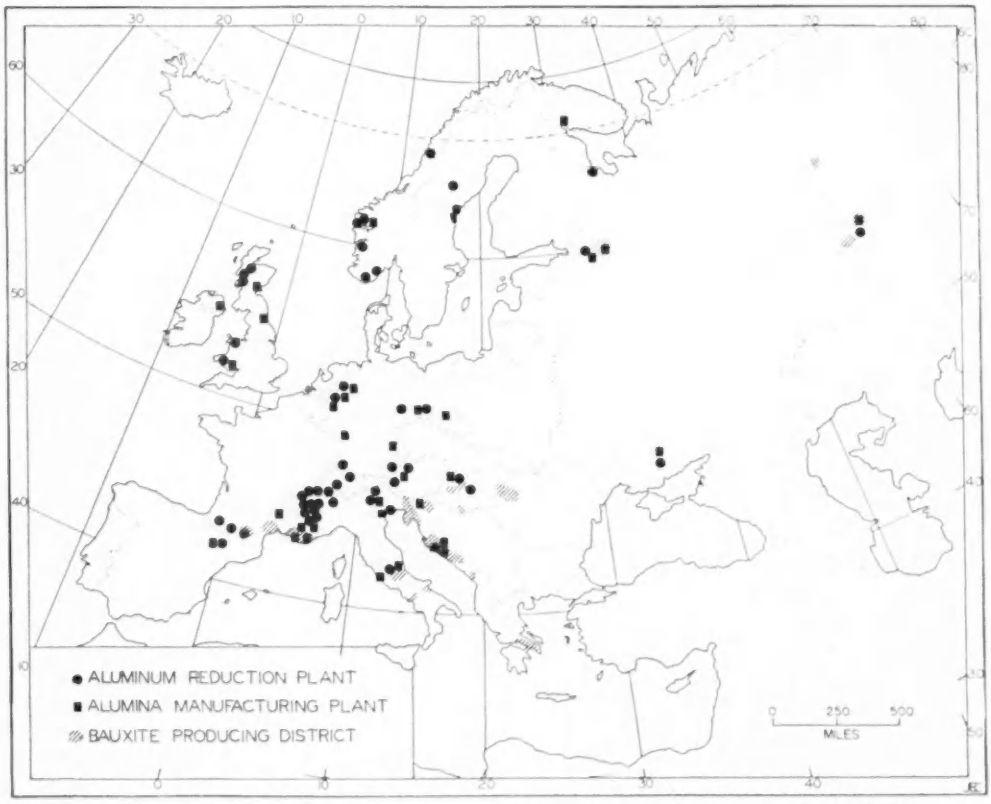

FIGURE 6.—Distribution of bauxite districts and alumina and aluminum plants in Europe.

Practically all of the bauxite produced in Greece is exported, since there is no aluminum reduction industry in the country. Plans were made in the

late 1930's for the construction of an alumina and aluminum plant, using electric power developed from falls in the Acheloos River in the southern Pindus Mountains. These plans were interrupted by the war, but may be completed later. Germany has been the leading consumer of Grecian bauxite, importing about one-half of the annual production between 1936 and 1940. Other prewar consumers were Great Britain, Japan, Norway, Sweden, and the United States. Only 1,000 tons were exported during the first nine months of 1940 and large stocks of undisposed bauxite were on hand early in 1941. It seems likely, therefore, that mining ceased during the war. Cessation of hostilities in Europe and at least partial resumption of peacetime trade relations should revive the mining activities in the near future.

ROMANIA

Romania's bauxite deposits lie in the Bihar Mountain region west of Cluj. Proven reserves are in the neighborhood of 10 million tons, although German experts estimated them at 40 to 42 million tons. Romanian reports speak of billions of tons. Much of the ore is of good quality but in general it is not as good in quality as that of Hungary. Production has been but 10,000 to 12,000 tons per year, although the estimated 1940 production was 40,000 tons. The ore occurs in semi-consolidated deposits which have to be mined by the use of explosives, making the production cost relatively high. Although the iron oxide content is considerable, modern refining methods are considered able to cope with its removal. However, this is a handicap in competing with better ores in world markets. The deposits are not very favorably located with regard to transportation facilities.

Romanian bauxite was mined in the Bihar district during the latter part of World War I and mining had been resumed just before the outbreak of World War II. An output of 12,000 tons, 0.3 per cent of world production, was reported for 1938 after long idle mines were reopened.

Hungary's aluminum consumption in the past has not exceeded 500 tons annually, and at the most approximately 2,000 tons of bauxite is required. Small quantities are consumed in non-aluminum uses, but clearly the major market for Romanian bauxite is in other countries. The district is far from markets and because of transportation difficulties can economically ship to Germany only. As a rule, Hungarian bauxite is preferred by German consumers because of the better quality.

OTHERS

Bauxite deposits are known in Austria, Ireland, Germany, Spain, and elsewhere, but the ores are low-grade and are not used for the production of aluminum. During and following the first World War, attempts were made to mine bauxite in two districts in Austria. Production was never more than 5,000 tons per year, and has now ceased entirely. It has been found more economical to import the small requirements of the aluminum plants in Austria.

Deposits containing limited quantities of low-grade bauxite have been known and mined in the North Ireland county of Antrim. The ore was temporarily used for aluminum reduction during the first World War, but the maximum annual output was not more than 15,000 tons. Later the ore was used for the manufacture of aluminum salts, but production declined and for a number of years it has been stopped entirely. The extensive aluminum reduction industry of the United Kingdom is now dependent entirely on imported

bauxite. Bauxite was discovered recently in Slovakia and discoveries elsewhere may occur. It would seem likely, however, that most of the valuable districts of Europe are already known.

MANUFACTURE OF ALUMINA AND ALUMINUM

Since its earliest development the aluminum industry has tended to center in Europe. The original isolation of the metal occurred in Denmark. The earlier thermo-chemical separation process was developed largely by a French scientist.

FIGURE 7.—Bauxite localities and alumina and aluminum plants in Yugoslavia and Istria.

The present two-stage process was discovered simultaneously in France, Switzerland, and the United States. Twelve of the fifteen aluminum producing countries of the world in 1939 were European. More than 60 per cent of the world's output during the decade prior to the outbreak of war was by European producers. Europe possessed more than one-half of the world's aluminum reduction capacity at the end of 1941.

Germany has been the foremost producer of aluminum in Europe since 1934, and one of the leading producers of the world. France has been a consistently important producer and in the earlier decades of the century ranked second only to the United States among world producers. Other important producers have been Norway, Italy, and Switzerland. The Soviet Union entered the aluminum production field in 1932 and has forged rapidly ahead in recent years, with an estimated output second only to that of Germany and France in 1940. Austria has operated a small reduction industry since before the first World War, which has been expanded during recent years of German control. Sweden, Hungary, Yugoslavia, and Spain are newer European producers with smaller outputs.

GERMANY

Germany's entry into the aluminum production field was later than several other countries of Europe, but since the first World War her annual output has surpassed that of any other producer on the continent. France, Switzerland and Great Britain all originated their production earlier, but the industry in these countries did not reach the size of Germany's. During the past two decades Germany was clearly the leading European producer of the metal. Second only to the United States among world producers, from 1938 to 1940 German output was greater than ours. During the decade ending in 1939 it constituted one-third of the total European output and exceeded the combined tonnages of France, the Soviet Union and Norway, other major producing countries in Europe.

Germany has no bauxite deposits containing aluminum-grade ore. Deposits occur in Hesse but the ore is low in alumina and high in iron and combined water content. Domestic ores were used during the first World War, but proved uneconomical. Attempts to utilize these

domestic ores have not met with success because of the greater cost of aluminum thus produced than metal from imported ores. Domestic production of bauxite totalled 1,700 metric tons in 1933, 4,600 tons in 1934, and 15,000 tons in 1935, but such small amounts are insignificant to the bauxite consuming industries. In recent years the domestic ores have been used mostly for the manufacture of abrasives and chemicals.

The lack of satisfactory domestic aluminum ore has stimulated research and experimentation in methods of using various clays and other aluminum-bearing materials. Technically satisfactory processes for producing aluminum from clay have been developed in Germany, and in 1939 8,000 tons of aluminum were produced from this source at a large-scale experimental plant at Lippe, Westphalia. This plant, jointly with the Lauta works were reported to be producing 50,000 tons of alumina annually from clay in 1941. The cost of aluminum from clay is about twice that from bauxite, however, and this has prevented its competition with the latter. Production from clay also involves the use of equipment different from that required in the usual Bayer process for the utilization of bauxite, and heavy investment in Bayer plants and in bauxite concessions handicapped the attempted utilization of clay.

In an effort to find some domestic raw material of sufficient abundance and cheapness, experiments have been made in Germany with phonolite. Phonolite occurs in certain rocks which are extensively distributed in various parts of Germany, especially in the volcanic Eifel mountains, in southern Swarzwald, Vogelsberg and Sudetenland. The best Eifel phonolite contains only 20 to 23 per cent of alumina, while commercial bauxite commonly contains a minimum of 50 per cent. In the production of aluminum from phonolite, there are by-products which have some value in the manufacture of cement and certain chemicals.

In spite of all attempts at self-sufficiency in aluminum raw materials, Germany at the outbreak of war was the world's greatest importer of bauxite as well as one of the largest producers of aluminum. Imports in recent years have totalled more than a million tons annually, almost one-third of the world's output. Practically all of this was supplied by various nearby European

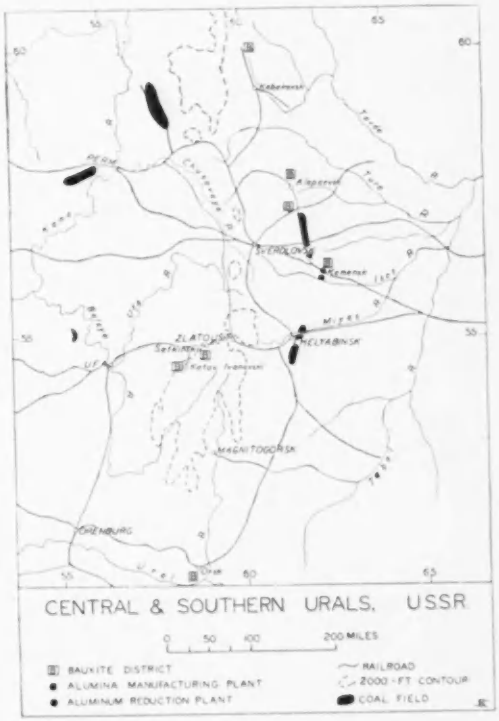

FIGURE 8.—Bauxite occurrences, alumina and aluminum plants, and coal fields in the central and southern Ural region.

countries. Hungary and Yugoslavia each supplied approximately one-third of the imports in 1938. Other sources include France, Italy and Greece, and in 1938 193,000 tons were imported from the Netherland Indies. Not all bauxite

imported by Germany was used for aluminum production. During the first eight months of 1936, approximately 40 per cent of the ore imported from France was used in the manufacture of chemical and other nonmetallic products.

Development: 1897–1918. The development of the German aluminum industry was handicapped by a lack of suitable ore and a deficiency of cheap electricity. Self-sufficiency in nearly all the required auxiliary materials, together with the very considerable demand for aluminum products and a reluctance to depend on imports, led to the growth of the gigantic industry which existed immediately prior to and during the first years of the second World War. This development from the early beginnings of the industry in Germany a scant half-century ago occurred chiefly in two short periods: from 1913 to 1918 during the first World War, and subsequent to 1934. The industry originated in 1897 with the construction of a small reduction plant at Rheinfelden, Baden. The annual output of this plant was about 800 metric tons, supplying only a small part of the domestic requirements.

Before the first World War, Germany, France and Switzerland comprised an economic unit in aluminum production. Of the three, France possessed good bauxite and cheap electricity but no good coal and little hydroelectric power, and Switzerland had only hydroelectric power. Bauxite mined in France was shipped to Germany for treatment in the preparation of alumina, and German alumina was supplied to reduction works in France and Switzerland. The latter two countries in turn supplied Germany with most of the crude aluminum required by her already well developed aluminum products manufacturing industry. This trade arrangement was disrupted by the outbreak of the first World War and was not afterward resumed on its former scale.

At the outbreak of war in 1914, with imports of aluminum cutoff, Germany was faced with the necessity of producing an adequate supply within her own borders. The increased demand resulting from the scarcity of copper and other metals emphasized the strategic value of aluminum production. The construction of five new reduction plants increased the output to a maximum of slightly more than 14,000 tons in 1918, after which production declined. Three of these located at Rummelsburg, Horrem, and Bitterfeld, respectively near Berlin, Cologne and Leipzig, used electricity generated at nearby or associated lignite-fired steam plants. They were designed to produce 9,000 tons annually, but were actually producing

FIGURE 9.—Distribution of aluminum production in Europe, 1934–1938 average. (Data from Minerals Yearbook and other sources.)

12,000 tons. Nevertheless, this did not meet the requirements and two more plants were established soon afterward. One of these was the Erftwerk at Grevenbroich, north of Cologne, with a designed capacity of 12,000 metric tons; the other and largest was the Lautawerk, near Lausitz in Saxony. Lignite-fired steam plants provided the necessary

electrical current in each case. In 1917 still another reduction works was begun, but it was not completed and put into operation until 1925. This was at Toging, on the Inn River in Bavaria, and was the first German aluminum reduction plant to be supplied with hydroelectric power.

The bauxite for this wartime aluminum industry in Germany was obtained from the Bihar region of Translyvania, from Istria, Dalmatia and southern Croatia, and from the Salzburg region of Austria, as well as from domestic deposits in Hesse. In the postwar period more attention was devoted to domestic ores, but the more attractive prices and better quality of Hungarian bauxite handicapped their utilization. Today domestic bauxite is used only in the production of abrasives, chemicals, refractories and for similar non-metallic purposes.

The expansion of German aluminum production during the first World War was handicapped not only by the absence of suitable domestic ore but also by the high cost of electricity. Neither of these difficulties has as yet been completely overcome. All of the producing plants of the period were supplied with electricity from thermal plants which used lignite as fuel. The works at Rummelsburg, Horrem and Bitterfeld were closed after the war because of the consequent high cost of production. The Inn River plant, although expanded recently, has been handicapped by the limited amount of hydroelectric energy available in the vicinity.

Development Subsequent to 1934. Germany's leading position as an aluminum producer at the beginning of the present war was due largely to a phenomenal growth since 1934. The total output of 1933 was 18,300 metric tons. In 1934 this was more than doubled, as it was again in 1935. The annual production rose from 70,700 tons in 1935 to 97,200 tons in 1936, 127,500 tons in 1938 and 161,100 tons in 1939. The output of crude aluminum in 1939 was estimated at 200,000 tons and at 240,000 in 1940 (Figure 12). In 1941, the combined German and Austrian production was variously estimated at from 300,000 to 350,000 tons.

German aluminum production since the period of expansion beginning in 1934 has supplied the total domestic requirements. Imports during the five-year period from 1935 to 1938 averaged 11,576 tons annually, but exports balanced them almost exactly, averaging 11,519 tons per year during this period. Of the 14,521 tons imported in 1938, 5,843 tons were obtained from Canada, 3,425 tons from Switzerland, 2,739 from Norway and 1,656 from the United States. Exports were chiefly to the non-aluminum producing countries of central and eastern Europe.

Distribution of Constituent Plants. The alumina and aluminum plants of Germany at the beginning of the second World War were relatively widely distributed. In general, however, they were located in three regions: (1) in the Rhineland and Westphalia, (2) in Saxony and adjacent Silesia, and (3) in Bavaria. In the first of these were three alumina plants at Duisberg, Bergheim and Lunen, and two reduction plants at Grevenbroich and Lunen (Figure 6). These locations are favorable for the receipt of bauxite by sea from Yugoslavia, Greece, Italy and other coastal fields after transshipment up the Rhine River. Both coal and lignite are available in the region. The plants are also oriented with respect to the fabricating plants in the industrial Rhine valley and associated regions.

The Goldschmieden and Lauta alumina plants, respectively in Silesia and

Saxony, received bauxite from Hungary and prepared it for reduction in the aluminum works at Lauta and Bitterfeld, both in Saxony. Both coal and lignite are available as fuel for these plants. The Innwerke at Toging, near Muhldorf, Bavaria, secured alumina from several sources until the construc-

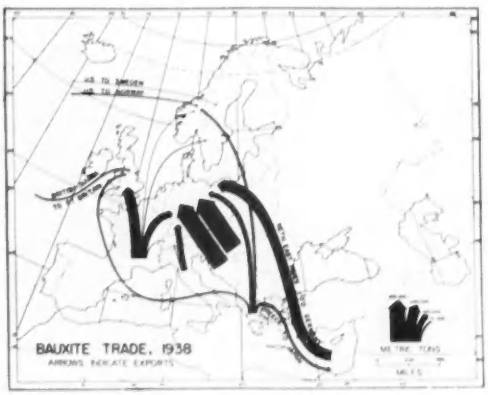

FIGURE 10.—European bauxite trade, 1938. Exports were chiefly from southern to central European countries.

tion of the new Nabwerk alumina plant at Schwandorf in 1938. This latter plant profited from a short haul and cheap transportation on the Danube River in receiving bauxite from Hungary. Transportation costs of bauxite from the Gant region of Hungary to this plant are reported to be less than one-half the costs by rail to the Lauta works near Leipzig. Southern Germany was thus favored over other sections in the utilization of Hungarian bauxite. The hydroelectric energy of the Inn River installation is the locating factor of the Toging reduction plant. The Rheinfelden works in Baden is supplied with alumina from the Bergheim plant near Cologne and from the independent Mundenheim alumina plant near Ludwigshaven (Figure 6).

Problems. Several problems have been confronted in the development of German aluminum industry. The dependence on foreign sources of bauxite has been partially alleviated by concessions granted to German concerns in some of the bauxite-mining countries. Commercial control and political influence in a manner guaranteed the supply so long as these controls could be retained. The average cost of aluminum produced in Germany was considered to be about 10 per cent higher than in most countries, chiefly because of the higher cost of the steam-generated electricity used for the major portion of the output. Practically all other producing countries use hydroelectric power exclusively. The deficiency of good water power sites and the abundance of coal and lignite has produced this situation in Germany. Only the Rheinfelden and Inn River reduction plants use hydroelectric power and their output in 1938 was only about one-fifth of the total. Competition with other demands for the available electricity tends to increase its cost, and economical aluminum reduction requires relatively cheap electricity.

Carbon electrodes for the reduction plants formerly were made from petroleum coke imported from the United States. In recent years, however, most of the requirements have been supplied from the byproducts of German petroleum refineries, and from pitch recovered from domestic coke works, synthetic gasoline plants and other sources.

Aluminum Substituted for Scarce Metals. In addition to the normal uses for aluminum, Germany was interested in developing the industry in order to be able to substitute aluminum for the more scarce metals. Copper, lead, tin and zinc were notably deficient. During the period from 1934 to 1938 the total mine output of copper was 147,000 metric tons, the smelter output was 306,700 tons and consumption 1,210,800 tons. Thus the domestic output was

about 12 per cent of consumption and smelter output 25 per cent. During the same period, 35,200 metric tons of lead were mined, 747,200 tons refined and 1,033,700 tons were consumed. The tonnage mined was about 34 per cent of consumption, and about 72 per cent of the requirements were derived from German refineries. The smelter output of tin was 37,300 tons and consumption 88,500 tons. The mine output of zinc (848,700 tons) was about 79 per cent of consumption, and smelter production (691,200 tons) about 64 per cent. The total consumption was 1,080,900 tons.

The emphasis on aluminum as a strategic metal to substitute for more scarce ones can be seen in the comparative increases in the consumption of the various metals from 1929 to 1938. Consumption of aluminum increased 442 per cent, copper 76 per cent, lead 20 per cent, tin 23 per cent and zinc 35 per cent. Consumption of aluminum increased from 32,600 metric tons in 1929 to 176,600 tons in 1939. Since Germany better controlled the sources of aluminum raw materials, wherever possible aluminum was substituted for the other metals. The extent of substitution was probably still greater after 1939.

Wartime Developments. Already the world's greatest producer of aluminum, during the war Germany gained control of still greater aluminum production capacity. The conquest of France gave her bauxite mines, alumina and aluminum plants, hydroelectric installations, and fabrication facilities. The occupation of Norway gave cheap hydroelectric power and aluminum plants, and Denmark yielded stocks of Greenland cryolite, although this latter was no longer a critical material in the German aluminum industry since synthetic cryolite had already made it independent of natural sources. Germany's dominating influence over Hungary, Yugoslavia, Greece, Romania, Italy, Austria and Switzerland gave access to bauxite and additional aluminum producing and fabricating facilities. In addition, three new reduction plants with a total capacity of 50,000 tons were reported under construction in Austria in 1941, two on the Inn River below the Innwerke plant and the third on the Enns River. In spite of the difficulties of overburdened transportation facilities, labor shortages, the heavy demand for steam and electric power by other industries and damages inflicted by Allied bombing, Germany did not suffer from a lack of aluminum.

FRANCE

France was the founder of the aluminum industry. The pioneer chemical process for the separation of metallic aluminum from oxygen was developed there in the middle of the nineteenth

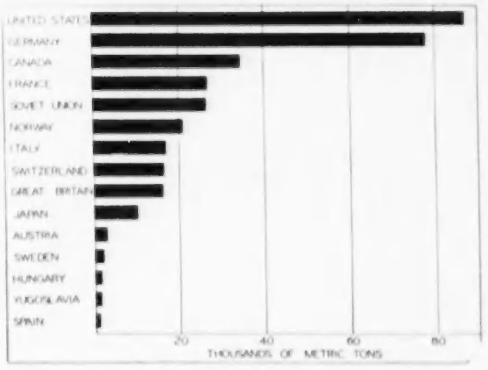

FIGURE 11.—Aluminum output of the leading producing countries, 1930–1939 average, except Soviet Union (1932–39), Japan (1934–39), Austria (1930–38), Sweden (1934–39), Hungary (1937–39), Yugoslavia (1937–39), and Spain (1930–36, 1938–39). (Data from Minerals Yearbook and Mineral Industry.)

century. A Frenchman, simultaneously with an American was responsible for the discovery and commercial application, of the electrochemical process which succeeded the more expensive chemical separation after 1886. This Hall-Herault electrochemical process is

essentially unchanged in its application to present-day reduction of metallic aluminum. This early start has been a factor in the importance of France in the modern aluminum industry.

Distribution. The aluminum manufacturing industry of France centers south and east of the Rhone River (Figure 4). Only one of the five alumina producing plants and three of the fourteen aluminum reduction works are west of the Rhone. The alumina manufacturing plants are located at La Barasse, St. Louis des Aygolades and Gardanne in the department of Bouches du Rhone, at St. Auban in Basses Alpes, and at Salindres in Gard (Figure 4). The first three lie at or near the Mediterranean coast between the bauxite mining districts in Var and in Bouches du Rhone. The alumina plants are thus favorably located for processing the bauxite of these districts, either for shipment to the reduction plants lying to the north, or for exporting alumina through Mediterranean ports. The St. Auban plant on the Durance River in Basses Alps refines Var bauxite for use in the reduction plant at the same location. The plant at Salindres uses Herault bauxite and supplies alumina to the reduction plants on the northern slopes of the Pyrenees.

The aluminum reduction industry of France centers farther north in the Alpine departments of Savoie, Haute Savoie and Isere south of Lake Geneva. Five of the fourteen reduction works are in Savoie, two in Haute Savoie, two in Isere, and one in Hautes Alpes. Another is at St. Auban in Basses Alpes. The remaining three locations are in the departments of Ariege, Hautes Pyrenees and Basses Pyrenees, all on the northern slopes of the Pyrenees Mountains. Approximately 70 per cent of the total is produced in the Alpine region and 30 per cent in the Pyrenees.

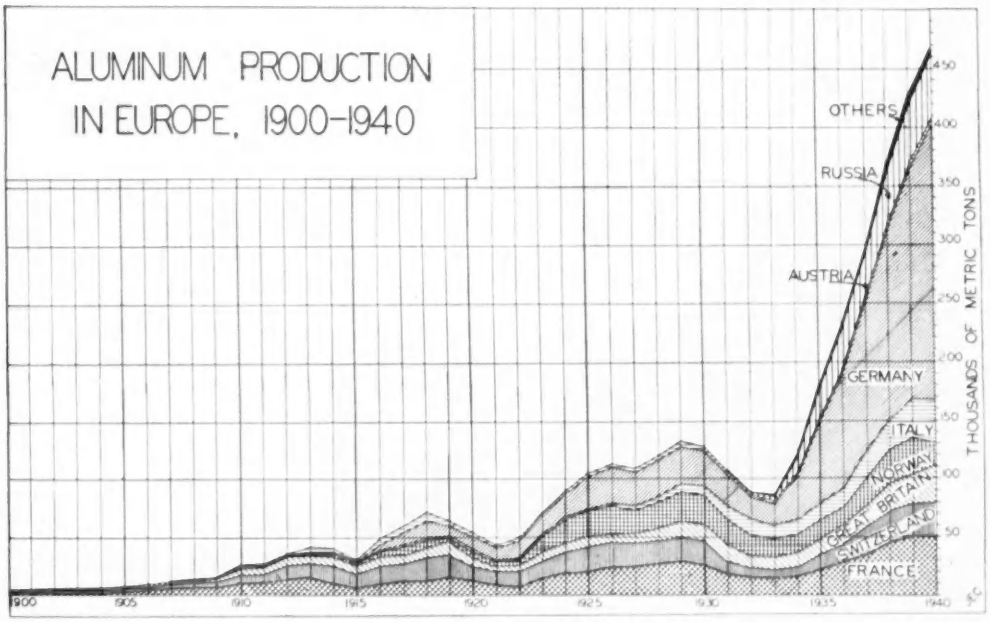

FIGURE 12.—Aluminum production in Europe, 1900–1940 (1940 estimated). (Data from Minerals Yearbook and other sources.)

Power. The electrical power needed for the reduction of aluminum in France

is supplied by hydroelectric developments on the streams of the Alps and Pyrenees Mountains. The reduction plants are all situated on or near these streams. East of the Rhone, the thirteen aluminum plants are on the Arc, Durance, Arve, Romanche and Fier rivers, all tributaries of the Rhone having their headwaters in the Alps Mountains. Two of the plants in the Pyrenees are on the Ariege and Neste rivers. Most of the reduction works have their own power stations. Others use energy purchased from nearby developments. There are many interconnecting transmission lines among the power plants of the Alps, Pyrenees and Massif Central to guarantee a continuous power supply. Since the streams of this region are relatively small and short, practically all of the water power sites are limited in their energy output. For this reason more than any other, the reduction works are small. The largest of the fourteen units has a capacity of only 6,000 tons annually. Most of the French aluminum plants are integrated with other consumers of electrical current. The plant at Venthon near Lake Annecy in Haute Savoie, for example, is one of three aluminum producing plants of eighteen large electrochemical, electrothermal and electrometallurgical works of a single concern. Twenty-three hydroelectric installations supply energy for these eighteen factories.

Production Trends. The aluminum reduction industry in France is one of the oldest and most permanent in Europe. The natural conditions for the industry are probably the most favorable on the continent. Bauxite and hydroelectric energy are conveniently located with respect to each other. The added economic factors of industrial development and demand for the product result in the industry's more logical development here than in almost any other country.

The development and annual production in France has been relatively more stable than elsewhere. Only minor changes have interrupted the regular increase of output (Figure 12). Metal production rose gradually from 1,000 metric tons in 1900 to 14,500 tons in 1913, declining to 6,000 tons in 1915. The stimulus of the first World War increased this to 15,000 tons in 1919 followed by another slight decline. The annual figure rose from 7,500 tons in 1922 to 29,000 tons in 1929, after which the depression in world aluminum markets led to a decrease to 14,300 tons in 1933. An upward trend set in immediately and an all-time maximum of 50,000 tons was reached in 1939 and 1940. The output was believed to have fallen below the objective of 70,000 tons in 1941 because of the lack of railroad transportation, skilled labor, an adequate coal supply and hydroelectric power. Early in 1942 production was reduced two-thirds because of power difficulties, although the output was reported to have returned to normal by April of that year.

UNITED KINGDOM

Development. The modern British aluminum industry had its origin in the development of bauxite mining in County Antrim, North Ireland, in 1896. The ore was processed nearby at Larne, and reduced to metallic aluminum at Foyers, Inverness-shire, Scotland, where the required electric energy was obtained from a local hydroelectric installation. Production facilities were expanded with the opening of an additional reduction works at Kinlochelvn, Argyllshire, Scotland, in 1907, again using locally generated hydroelectric power. One year later a third reduc-

tion plant began operation at Dolgorog, northern Wales.

Although the early development of aluminum production was based on the use of Irish bauxite, this ore soon proved to be uneconomical because of its low alumina content and a consequent greater cost of metal production. Beginning in 1897 French bauxite was imported and the output of domestic ore, which was never great, experienced a marked decline. Other bauxite producing regions later contributed to meet the British ore requirements, but France has consistently supplied the bulk of the imports. Irish bauxite has been used successfully for the manufacture of refractories and various aluminum salts, but for several years none has been used for aluminum reduction.

Aluminum production in Great Britain is thus founded on the basis of imported bauxite, which is processed with the use of domestic coal. The final reduction process involves the use of cryolite, most of which is imported from Greenland via Denmark, and large quantities of hydroelectric energy which is generated in the more rugged portions of Scotland and Wales.

Distribution. In addition to the plant at Larne, North Ireland, alumina is manufactured at Burntisland, Fifeshire, Scotland, at Hebburn, Newcastle-on-Tyne, England, and at a recently constructed plant at Newport, Wales (Figure 6). All can receive imported bauxite at tidewater, and coal is obtained from nearby fields. In addition to Foyers and Kinlochelyn, in Scotland, and Dolgorog, Wales, alumina is reduced to metallic aluminum at Fort William and Lochaber in Inverness-shire, Scotland, and at a fifth plant which was recently constructed at Resolven in the Neath Valley of southern Wales. All these consume hydroelectric energy in the separation process and are located at or very near tidewater for economical receipt of alumina shipped by water from coastal locations.

Bauxite Imports. France normally supplies approximately three-fourths of the bauxite imported by Great Britain. During the five-year period from 1934 to 1938, the average annual imports from this source was 153,125 metric tons, 58.5 per cent of the total French exports. British Guiana, before the war, was second to France, but the annual imports were only 15,000 to 20,000 tons. During the period prior to 1940, Greece and Netherlands East India were becoming of increasing importance as sources of bauxite. Imports into Great Britain from Greece increased from 7,900 metric tons in 1935 to more than 18,000 tons in 1937 and almost 24,000 tons in 1938. In 1940, 14,469 tons of ore were imported from Netherlands East India. Most of the bauxite mined in this area had previously been exported to Germany and Japan.

Prewar Production. Great Britain ranked ninth in world aluminum output, and seventh among European producers. The United States, Germany, Canada, France, Soviet Union, Norway, Italy, and Switzerland produced greater amounts during the decade from 1930 to 1939 (Figure 11). The aluminum output of Great Britain, designed to meet as much as possible of her domestic requirements, has been relatively consistent from the beginning (Figure 12). From 70 metric tons in 1890, production rose gradually to 550 tons in 1900 and to 5,000 tons in 1910. Wartime stimulation pushed the output to 8,300 tons in 1918, but it had dropped back to 5,000 tons in 1920. Through further gradual expansion the industry produced 14,000 tons of crude aluminum in 1930. A maximum output of 32,000 tons was realized in 1940.

Imports. The production did not

keep pace with the rapidly increasing domestic requirements, and imports grew steadily. The domestic industry supplied approximately 60 per cent of consumption in 1925 and only a little less in 1930. More than half the needs of metallic aluminum were imported in 1936, however, and British production supplied 40 per cent or less of the needs in 1937 and 1938.

Imports were chiefly from Canada, although Switzerland and Norway supplied part of the demand. Imports from Canada were less than 5,000 tons in 1929, but had more than tripled by 1935. The tonnage was more than 30,000 in 1938 and was estimated at 39,000 tons in 1939—more than the domestic production. Following the capitulation of France and the loss of available sources of bauxite, British aluminum production declined rapidly to negligible quantities and Canada has supplied most of the wartime needs. When bauxite is again available from France, Greece and Yugoslavia, British industrial production will no doubt regain essentially its prewar status and resume production at about its former level.

SOVIET UNION

The Soviet Union is one of the newer producers of aluminum, yet in the short time since its entry into the industry it has risen rapidly and now ranks third among European nations and fifth in world production (Figure 11). Only the United States, Germany, Canada and France had greater outputs of crude aluminum during the period immediately preceding the outbreak of war in Europe.

Russia's entry into the primary aluminum production field dates from the construction of the Volkhov reduction plant in 1932. Prior to that time domestic requirements of the metal had been met with imports. Before the first World War consumption of aluminum in Russia was small. In 1913 the total imports were about 1,800 metric tons. Military needs during the war increased annual imports to about 6,300 tons—the largest of any year before the Revolution and for several years afterward. Annual imports increased to 6,544 tons in 1929 and to more than 20,000 tons in 1931. The amount dropped to 10,498 tons in 1932, the first year of domestic production (about 900 metric tons), and declined rapidly as domestic production met an increasingly greater part of the requirements. In 1935 the imports were only 538 tons, and in 1936 they had dropped to 17 tons. In 1937, 2,547 tons of primary aluminum were imported and a larger amount in 1938, evidently for stockpiling purposes. Norway and France supplied most of the imports.

Tikhvin-Volkhov District. The Volkhov aluminum works is about 75 miles east of Leningrad and includes an aluminum plant which processes bauxite from the Tikhvin deposits, about 63 miles to the southeast by railroad, as well as the electrolytic reduction plant. Electric current is supplied by the 66,000 kw. Svanka hydroelectric power plant on the opposite side of the Volkhov River. The original capacity of the combined plant was 13,000 tons of alumina and 6,000 tons of aluminum, conforming to the usual ratio of approximately two tons of alumina to one ton of aluminum. In 1934 the actual output was 12,740 tons of alumina and 5,832 tons of aluminum. The capacity of the reduction plant was later increased to 15,000 tons and in 1939 and 1940 it produced about 13,000 tons of aluminum annually. The alumina capacity was increased to 25,000 tons to meet the increased requirements of expanded aluminum reduction capacity.

Because of the poor quality of Tikhvin

ores and the relatively high cost of Svanka electricity, the production cost of Volkhov aluminum has been greater than is considered economical. Because of the high silica content of Tikhvin ore, a special process is required. This, together with the lower rate of recovery, results in the cost of crude metal being about four times as great as in most countries.

Dnepr Works. The second Soviet aluminum reduction plant began production at Neproges on the Dnepr River in 1935 (Figure 6). The original construction included a 32,000-ton alumina plant, a 20,000-ton aluminum works, a 17,000-ton carbon electrode factory, and a plant for refining 3,800 tons of cryolite per year. The crude cryolite was supplied by the Polevskoi cryolite factory in the Urals which obtains its fluorspar from Soyusplavik in Eastern Siberia. The aluminum reduction capacity had been increased to 35,000 tons in 1940. Bauxite and part of the required alumina was supplied from the Tikhvin district, more than 1,000 miles to the north. The electric power was obtained from the 900,000 kilowatt hydroelectric installation on the Dnepr River. The cost of producing aluminum at the Dnepr plant was considerably lower than at the Volkhov works, but it was still about two and one-half times the average cost of the world's leading producers. During the second World War the retreating Russians destroyed the Dnepr dam, and presumably the aluminum production facilities as well, in order to prevent their falling into German hands. The Volkhov facilities probably were also destroyed. Equipment from the Dnepr plant is believed to have been moved to Kamensk or elsewhere in the Urals.

In order to meet the alumina requirements of expanded aluminum production at both the Dnepr and Volkhov works, a new 50,000-ton alumina plant was completed in the Tikhvin bauxite district in 1937. The capacity of the Dnepr plant was increased to 35,000 tons of aluminum and in 1939 it supplied 31,000 tons of metal, 69 per cent of that year's total output. Its production in 1940 was estimated at 32,000 tons.

Kola Peninsula Area. The third region of the Soviet Union to enter the aluminum production field was the Kola Peninsula–White Sea area. In 1937 alumina was first produced at Kandalaksha from the waste material of apatite rock mined at Khibinogorsk in the Kola Peninsula. The 20,000-ton plant supplied alumina for the 10,000 electrolytic reduction plant which began operations in 1939 at Sosnovetz on the border of the White Sea. Sosnovetz is about 200 miles south of Kandalaksha, both being located on the Murmansk Railroad for convenient transportation of materials and the finished metal. Water power for dams on the White Sea–Baltic Canal supplied the necessary electric energy. About 60,000 kilowatts is available in the vicinity.

Ural Province. After the discovery of extensive deposits of better-quality bauxite in the Ural region, aluminum production facilities were established in this area. Bauxite from the Kamensk district and from the Kabakovsk district about 300 miles to the north is processed and aluminum is manufactured at Kamensk on the Yset River (Figure 8). There is also an associated alumina-cement factory. Electric power for operation of the reduction cells was supplied by a lignite-fired steam plant, which was to have been replaced by a hydroelectric installation on the Yset River. The output in 1940 was approximately 10,000 tons of primary aluminum. The production capacity was 25,000 tons and the completed capacity

was originally planned for 50,000 tons. Wartime expansion has probably increased the capacity beyond this figure. According to Soviet sources, the cost of producing aluminum at the Ural plant compares favorably with the costs of leading foreign producers.

The presence of good bauxite and most of the required raw materials, including coal, which can be brought together over short distances to a source of hydroelectric power makes the Kamensk district one of the most favored in all the Soviet Union for aluminum production. The alumina capacity in 1940 was out of balance with respect to the requirements of the aluminum plant and the reported intentions were to supply alumina as soon as possible to both the Volkhov and Dnepr reduction plants. Since the processing cost of Ural bauxite is less than that of Tikhvin ore, the Volkhov plant may economically be supplied with alumina from Kamensk, in spite of the 1,200 miles distance which separates them. The Dnepr works earlier was supplied with Tikhvin bauxite and alumina so that the use of bauxite and alumina from the Urals might here too be practical. The greater distance from Kamensk (1,500 miles) than from Volkhov (1,000 miles) would be offset by cheaper bauxite and alumina for use in the Dnepr plant. Probably a savings at both Volkhov and Dnepr plants would result.

Problems. The general conditions have not been favorable to industrialization in the Soviet Union and the aluminum industry has been handicapped in several ways. A major problem has been in the quality of the available bauxite. The ore of the Tikhvin has a high silica content which makes alumina produced from it considerably higher in cost than from better quality bauxite. Conversion to the use of the better ores of the Urals should give some relief from this difficulty and considerably reduce the production costs of aluminum. A second important problem has been the high cost of electricity. The Soviet Union possesses about 36 per cent of the world's water power resources, but only about one per cent of this has been developed. A number of industries bid for the use of power from existing installations which for the most part have been built at unusual expense. The consequent cost is too high for economical aluminum production. In addition the efficiency of electrical consumption has not been of the greatest. Even by using power from the huge Dneperstroi project at the Dnepr aluminum plant, the price per kilowatt hour is double that of electricity in the United States, and the amount of electricity needed to produce a ton of aluminum from Russian ore is greater.

Still another difficulty to aluminum production in the Soviet Union has been the long distances between raw materials, and between reduction plants and aluminum consuming industries. Tikhvin bauxite and Volkhov alumina have been transported a thousand miles by rail to the Dnepr reduction plant. Fluorspar is mined in Eastern Siberia and artificial cryolite is manufactured in the Urals, to be consumed at the Volkhov and Dnepr plants respectively 1,000 and 1,200 miles away.

Outlook. The outlook for Soviet aluminum production seems good. Continual improvement of the handicaps of early conditions points to eventual maturity of the industry and economical production comparable to other advanced manufacturing nations. Wartime damage was severe, including Soviet destruction of the huge Dnepr dam and installations in the path of the advancing German army and probable destruction of the Volkhov plants. Equipment from the Dnepr plant is

believed, however, to have been moved to Kamensk or elsewhere in the Urals. Moreover, these damages may be considered only temporary and reconstruction can take advantage of the lessons learned earlier to re-establish production on a more economical basis.

NORWAY

The Norwegian aluminum industry well illustrates the strong locational effect on aluminum production of cheap hydroelectric energy near good seaports. Bauxite, coal and virtually all requisites other than electricity are lacking, including a large domestic market. Yet Norway ranks fourth among European and sixth among world producers of the metal (Figure 11). Her average normal output of more than 20,000 tons is greater than that of Italy, Switzerland, Great Britain, Japan, and the several minor producing countries. Only the United States, Germany, Canada, France and the Soviet Union had greater prewar production.

Development and Distribution. The attractions of Norway's wealth of low-cost electric power conveniently available at coastal locations were recognized relatively early in the development of world aluminum production and the first plant to be located here was constructed in 1908 at Stangfjord, north of Bergen. Since it was a subsidiary plant of the British Aluminum Company, its alumina was supplied by the controlling company and most of its output was returned to Britain. Electric current for its reduction cells was obtained from an associated waterpower development. At about the same time a reduction unit was erected at Vigelands, near Kristianssand in southern Norway, again under the auspices of British interests. Other early centers of aluminum reduction were established at Eydenhaven, near Arendal on the Kristiananfjord in 1914, and at Tyssedal on the Soerfjord in 1916. Additional works have since been established at Hoyanger on the Sognefjord and at Glomfjord in northern Norway (Figure 6). All these are directly on the coast or on fjords.

Only the Hoyanger reduction plant has an associated alumina manufacturing plant and can process imported bauxite. All the other works use alumina imported chiefly from France, Great Britain or Germany. These imports averaged approximately 31,000 tons annually from 1930 to 1939. Bauxite imports, chiefly from Greece, the United States and France, averaged 26,000 tons during this period.

Production and Exports. In spite of the commercial nature of the industry and its dependence on foreign markets, Norway's aluminum output has experienced no marked fluctuations such as characterized some producers. Production increased slowly from 600 tons during the first year after the industry was established until 1922. The output jumped from 4,900 tons in that year to 13,300 tons the following year, then continued its steady increase until the first decline following 1930. The output of 15,400 metric tons in 1936 was the lowest since 1923. The 1939 tonnage of 31,100 was the maximum since the establishment of the industry (Figure 12).

The aluminum production of Norway is primarily commercial in its nature. Before the war, 93 per cent of the total output was exported as crude metal. Norway thus led Europe and, except for Canada, the world in aluminum exports (Figure 13). No one nation is outstanding in purchasing this aluminum. The United Kingdom, Japan, Germany, the Soviet Union and the United States each bought from 1,500 to 6,000 tons annually, and numer-

ous countries of Europe secured small amounts of the metal.

ITALY

Factors Affecting Aluminum Production. The presence of adequate supplies of bauxite and hydroelectric power fostered the development of aluminum production in Italy. Inferior bauxite somewhat handicapped the industry prior to the acquisition of Istria in 1919,

FIGURE 13.—European trade in aluminum, 1938. (Data from Minerals Yearbook and other sources.)

but the ore of peninsular Italy was sufficient to establish the industry. The greatest development occurred subsequent to the utilization of Istrian deposits, which have supplied the greater part of the ore requirements since they have been available. About 97 per cent of the total electrical energy output of Italy is hydroelectric and all of the aluminum reduction plants are operated with this type of current. It is generally lower in cost than steam generated power, a factor of considerable importance in economical aluminum reduction. Plans had been made in 1938 for the development of several additional sites in order to insure ample power for the increasing needs of the industry.

Italy is also self-sufficient in production of the chemicals necessary for aluminum reduction, but lacks the required coal, as well as coke suitably pure for making electrodes. Various materials were formerly imported and are now supplied domestically, but the fuel situation cannot be much improved. Italy produces a low grade coal in Istria and Sardinia, but proved reserves are small. A government program called for an increased output during the period 1936 to 1940, but more than 90 per cent of the total coal consumed is normally imported. Because of the lack of coal there has been especial interest in electro-thermal methods of producing alumina. The Haglund smelter process was tried at two of the Italian plants, but it was discontinued in favor of the standard Bayer process which requires coal.

The desire to substitute aluminum, which can be produced in Italy at a cost as low as in most other countries and lower than in some, for certain deficient minerals has been a major stimulus to the reduction industry. Outstanding deficient minerals are copper, lead and tin. The combined primary and secondary production of copper during the five-year period from 1933 to 1937 was less than 0.6 per cent of the consumption. For the same period the output of lead supplied 53 per cent of the requirements. Neither copper nor lead output can be increased substantially, and tin is entirely lacking. Where possible it has been the policy to substitute aluminum for these metals.

Development and Production Trends. Aluminum reduction in Italy began in 1908 with an output of about 600 metric tons. The growth of the industry has been quite steady (Figure 12). The annual output of primary aluminum has been less affected by periods of depression in world markets than that of most other countries, probably in large part because of government regimentation. An additional factor is that

Italian producers have depended largely on domestic rather than world markets for the sale of their product. The aluminum requirements were small prior to the first World War. This lack of a large home market, as well as dependence on low-grade ore, handicapped the early progress of the industry, but government policies of the decade prior to the second World War greatly stimulated the demand, practically all of which was supplied by domestic production.

Domestic production and consumption of aluminum in Italy have not always kept apace. During the period from 1920 to 1926 consumption was greater than production and imports were substantial, reaching a maximum of 6,500 tons in 1925. Between 1927 and 1930 production and consumption fairly well balanced, but between 1931 and 1934 production was in excess of consumption and an exportable surplus resulted. The 1930's was the decade of the maximum expansion of the Italian aluminum industry. More recently production and consumption have been very nearly equal, with production slightly greater. Exports increased from virtually none prior to the first World War to 6,000 tons in 1935. The tonnage rose from 642 tons in 1918 to 2,891 tons in 1919. From the maximum of 6,271 tons during 1935 the figure dropped to 70 tons in 1936. Import trends were logically the reverse of exports, reaching a maximum of 6,500 tons during the 1920's and dropping to almost nothing during the middle 1930's. Imports were 3,700 tons in 1937 but only 530 tons in 1938. Trade has been almost entirely with other European countries, exports being chiefly to Great Britain and Germany and imports being mostly from France.

As in most other countries, Italy's expansion of aluminum production occurred chiefly during two periods: during the first World War, and in the years immediately preceding the second World War. Approximately 800 tons were produced annually from 1908 to 1913. The output rose to 1,700 tons during 1917, 1918, and 1919. The general postwar decline in aluminum output was felt in Italy, but to a lesser extent than in some of the other producing countries. Gradual recovery began almost immediately and by 1924 the earlier maximum output figure was reached and passed. The tonnage of 1926 was almost doubled in 1928 and more than 10,000 tons were produced for the first time in 1931. Nearly 23,000 metric tons were refined in 1937 and the estimated output in 1940 was 36,000 tons (Figure 12). The average production by decades significantly charts the growth of the industry in Italy. The average annual output from 1911 to 1920 was slightly more than 1,000 tons. From 1921 to 1930 it was 3,000 tons, and during the decade ending in 1940 it was more than 20,000 tons. During this last decade Italy ranked seventh among world producers and fifth in Europe. The United States, Germany, Canada, France, Soviet Union and Norway produced more, and Switzerland and Great Britain were only slightly lower in average output (Figure 11).

Distribution. Italy's aluminum industry is located in both central peninsular Italy and in northern Italy on the Po plain and the slopes of the Alps. The central Apennine region contains two alumina manufacturing plants and one reduction works. Near Venice on the Po plain is one of the larger centers of manufacture, both of alumina and aluminum, with three plants of each type. On the Alpine slopes of northern and northwestern Italy are three aluminum manufacturing centers, one of which also produces alumina. The

major part of the industry thus is in the north where water power is more abundant and where Istrian bauxite is more conveniently available (Figure 6).

At Bussi on the Pescara River in the province of Abruzzi of central Italy is a completely integrated unit for processing bauxite and reducing primary aluminum, supplying also carbon electrodes for the electrolytic cells. Constructed in 1907, this unit was the original center of the industry in Italy. This development is about 60 miles from the bauxite deposites of Lecce dei Marsi in the eastern Apennines, earlier the only important source of bauxite in Italy. In 1938 the capacity of the Bussi plants was 24,000 tons of alumina and 1,000 tons of aluminum. Most of the bauxite was supplied from the Istrian region. Only 2,000 tons of alumina could be consumed by the reduction works and the bulk of the alumina was shipped to northern Italian aluminum plants for final reduction to metal.

Also in the central Apennines is the alumina plant at Aurelia, near Civitavicchia, northwest of Rome. This was built in 1930 to produce alumina from leucite, with potash as a by-product. Its original capacity was 4,000 tons of alumina per year, and its output was shipped to a northwestern Italian reduction works for final processing. Because of various difficulties, chiefly operational costs, production was suspended after a few years. In 1939 the plant was converted to the Bayer process for utilizing bauxite, enlarged to a capacity of 6,000 tons, and reopened to help meet the increased alumina requirements of the Dorea Baltea reduction works north of Turin. Both Bussi and Aurelia now supply some alumina to this reduction works.

Porto Marghera, near Venice, is one of the largest Italian aluminum producing centers. Here there are three plants for refining bauxite and three reduction works. Bauxite from Istria is used, as well as ore from the more recently discovered Apulian district. The original reduction works began operations in 1928, with alumina supplied from Bussi. The original capacity of 7,000 tons was increased to 11,000 tons in 1937. A Haglund type alumina plant was established soon after the reduction unit. Two Bayer type alumina plants were constructed with the expansion of metal production capacity in 1937. The present alumina production capacity is greater than the requirements of the reduction units, the surplus being used at other northern Italian localities. The coastal location is a logical site for processing bauxite from Istria or Apulia before transportation to reduction centers near available hydroelectric power. The total Italian aluminum capacity in 1938 was approximately 30,000 tons, and even the additions planned during 1939–1941 to increase output to 50,000 to 55,000 tons annually would not require the total Italian alumina producing capacity reported to be more than 150,000 metric tons. Two additional reduction works increased the Porto Marghera capacity to 24,000 metric tons of metal in 1938, and further expansion was planned for the next three-year period.

Electricity for the original Porto Marghera aluminum reduction unit was transmitted from a hydroelectric installation in the upper valley of the Cismon River. Increased capacity in the aluminum plant required expansion of the power installation and even this was not enough to meet the greater demand. Approximately 170,000,000 k.w.h. were supplied in 1936 and supplemental electricity had to be obtained from outside sources, according to reports. Electric power for the Haglund smelter plant has

been furnished from several small developments on the Piave River.

At Mori, near the northern end of Lake Garda, both alumina and aluminum are made. The reduction works was constructed in 1928 with an initial capacity of 6,000 tons annually, which was expanded to 8,000 tons in 1936. Additional expansions were planned to bring the total capacity to 15,000 tons by 1941. The alumina plant which was constructed at the same time utilizes Istrian bauxite, originally refined by the Haglund thermal process. Electric current is obtained from a site on the nearby Adige River integrally developed by a subsidiary of the aluminum producing company. The capacity of the hydroelectric station is approximately 110 million k.w.h. annually.

One of the older of Italy's aluminum reduction works is the Borgofranco unit which was established in 1917 near Ivrea on the Dorea Baltea River north of Turin. Alumina is not produced here, but is obtained from other plants in Italy. Some was supplied by the Aurelia leucite plant until it was closed and it was expected to again be a source after its conversion and reopening in 1939. The Bussi unit has supplied alumina to the Borgofranco reduction works as needed. The capacity of the Borgofranco aluminum works was 1,600 tons in 1936 and plans were laid to increase this to 3,000 tons. Actual metal output in 1932 was 1,788 tons and 1,521 in 1933.

The newest of Italy's aluminum reduction works is that at Bolzano, near the junction of the Isarco and Adige rivers. This unit began operations in 1937 with an annual capacity of 8,000 metric tons. Alumina was supplied by a new Bayer plant at Porto Marghera. Electric current was first supplied from existing hydroelectric plants on the upper Adige River. During its initial year of operation, current was first received from a large station constructed at Bressanone, about 25 miles above Bolzano on the Isarco River. The total output of this station was about 200 million k.w.h. in 1938 and 2 billion k.w.h. were to have been supplied in 1942. Additions to the Bolzano reduction works were expected to double its capacity during the expansion period of 1939–1941. During 1940 plans for a capacity of 60,000 tons by 1942 were reported.

Non-bauxite Ores. In addition to bauxite, both alunite and leucite are aluminum-bearing materials which are found in Italy. Because of the possibility of early exhaustion of her bauxite resources, Italy has been seriously attempting to find other sources of alumina. There is a large amount of alunite at Tolfa, near Rome, and immense quantities of leucite occurs in association with the lavas of a row of old volcanoes extending northward from Naples for a distance of about 185 miles. About 100 billion tons of leucite are estimated to be contained in these occurrences, from which about 11 billion tons of alumina could be extracted. Processes have been developed and a plant was constructed at Aurelia in 1930 to extract alumina and potassium salts from this ore, but the attempt proved uneconomical. Experiments were under way in 1940 aimed at recovering alumina from leucite at Bagnoli, west of Naples. An alumina and potash plant at Castellina Chianta was reported, as well as the planned construction at Orvieta in the upper Tiber valley. In view of the failure of the Aurelia plant to economically process leucite, the success of these more recent attempts to extract alumina and potash in competition with bauxite seems questionable.

Outlook. The key to the future of the Italian aluminum industry seems to be the availability of Istrian bauxite. The

cost of producing aluminum in Italy compares favorably with that of most countries and is lower than in some. The necessity of importing coal for the alumina process is a handicap, but it is obviously not prohibitive. The availability of low-cost hydroelectric power is an advantage of major proportion. The possibility of the loss of bauxite from Istria looms large in the immediate outlook. Of course, Yugoslavian bauxite could be made available, probably at no greater cost than Istrian ore, although the certainty of supply through political control would be lost. The extent to which Apulian bauxite could replace Istrian ore, in the event of loss of control of the latter, is not immediately certain. A considerably increased output might adequately meet the probably more limited requirements of the postwar aluminum industry, but the known reserves do not justify long-time dependence on the field. A possible alternative is the use of leucite, but aluminum produced from this source would apparently be more expensive than that from bauxite.

SWITZERLAND

Switzerland, like Norway, has attracted the aluminum reduction industry with its hydroelectric power, but it has little else required by the industry. Switzerland shared with France in the pioneer development of aluminum production, first using a chemical process to produce crude aluminum and a thermal process for the production of aluminum alloys. Much of the success of the electrolytic process for reducing alumina to metallic aluminum is a result of its commercial application in Switzerland and in other countries by Swiss manufacturing interests.

The first electrolytic reduction plant in Switzerland was established in 1888 near Neuhausen at the Rhine River falls below Lake Constance. The founding company, Aluminium Industrie, A.-G., constructed works on the German side of the Rhine at Rheinfelden and at Lend-Gastein, Austria, in 1897. The company also had an interest in the aluminum reduction plant at Sabinanigo, Spain, and in alumina plants at Breslau, Germany, and St. Louis les Aygaylades, France. The Neuhausen company began its second works in Switzerland in 1905 near Chippis, Canton Valais, on the Rhone River in southwestern Switzerland. Five waterfalls on the Rhone and its tributaries in this area have combined to supply electricity to the Chippis reduction plant. Development of these sites extended from 1908 to 1928 with the increasing power requirements of the growing plant. At Martigney-Bourg, farther down the Rhone, is Switzerland's third aluminum reduction plant.

Switzerland has no bauxite and no alumina manufacturing plants, but imports all of its required alumina. Most of this is obtained from France and Germany, although Italy also supplies small quantities. Commercial and financial interests favor the former two. Lack of coal prevents the economical manufacture of alumina from bauxite which could be imported from France, Yugoslavia or elsewhere.

The manufacture of aluminum in Switzerland has from the beginning been chiefly commercial. The domestic requirements have not exceeded 6,000 to 8,000 tons until recent years. Approximately two-thirds of the output has been for export. The annual production increased from less than 1,000 tons prior to 1900 to 8,000 tons in 1910. Wartime stimulation accounted for a rise to 20,000 tons in 1920, but the output dropped to 12,000 tons the following year (Figure 12). The 20,000-ton mark was passed in 1930, but again the out-

put dropped, this time to a low of 7,500 tons in 1933, the least since 1910. Another wartime stimulation pushed production to 28,000 tons in 1939 and to an estimated 31,000 tons in 1940, but another severe drop is almost certain to have occurred during the war.

Exports of aluminum from Switzerland have been chiefly to nearby European consumers (Figure 13). In 1939 the United Kingdom imported more than 10,000 tons, but this was a severalfold increase over previous amounts which resulted from the abnormal conditions of the time. Germany imported some metal, but restrictions limited the amount. Not insignificant amounts of Switzerland's aluminum is normally exported as manufactured or semi-manufactured aluminum goods.

MINOR ALUMINUM PRODUCERS

Austria. Austria has no bauxite of economic value and none of the requirements for aluminum production except water power. A small output began with the establishment of a reduction plant at Lend in the upper Enns valley in 1897. The industry was expanded during the first World War as part of an attempt to meet the metal requirements of the Central Powers. A second reduction unit was constructed in 1917 near Gmunden, about 50 miles east of Salzburg. Alumina was manufactured at Lend and electric energy was supplied to both plants from nearby integrated hydroelectric installations. Bauxite was supplied from the Salzburg and Wochein districts during the first World War, but it later proved more economical to utilize Hungarian and other bauxites. Some alumina is manufactured in Austria, although some is also imported.

The aluminum output of Austria has never been very great. The domestic market is small and most of the limited production has been exported, chiefly to Germany. The output varied between 2,000 and 4,000 tons annually up to recent years. The greatest production of independent Austria was in 1937, when the combined total of both units was 4,400 metric tons. The reported capacity at the end of 1939 was 4,000 tons at Lend and 2,000 tons at Gmunden. Because of the undeveloped hydroelectric power, expansions were planned after annexation to Germany in 1938, but the actual increase realized is unknown at the present. Three new plants with a total capacity of 50,000 tons were reported to be under construction in 1941,—two on the Inn River below Toging and a third on the Enns River.

Yugoslavia. The production of metallic aluminum in Yugoslavia began in 1937 with the construction of a reduction unit at Lozovac, near Sibenik on the Dalmatian coast (Figures 6 and 7). Alumina was supplied from Ljubljana, where a plant had been established earlier to manufacture alumina for export, chiefly to Austria and Germany. Approximately 4,800 metric tons of alumina were exported in 1930, most of it to Austria. The Sibenik reduction unit had an original capacity of approximately 880 metric tons per year, but room was allowed for expansion to something approaching 1500 tons annually. Most of the output of metal was exported to the United Kingdom.

A second alumina plant in Yugoslavia was under construction at Lozovac in 1939. The plan was to process bauxite from the nearby Drnis-Knin region for reduction in the Sibenik electrolytic plant. In this manner, transportation of alumina from Ljubljana in northwestern Yugoslavia through bauxite producing districts would be avoided, the cost of production reduced, and most of the output of the Ljubljana plant would be available for export.

Aluminum output in 1938 was about 1,000 tons. In 1939, 1,642 tons of crude aluminum were exported, 995 tons of it to Japan. By 1940 the capacity of the Lozovac works had reached about 3,000 tons annually and the establishment of a reduction works near Mostar was planned.

In spite of a rapid growth, the future of Yugoslav aluminum does not seem too bright. Domestic requirements are small and probably will never be very large. Because of restrictions on imports of metal in most countries, bauxite can be exported much more readily than aluminum. On the other hand, coastal bauxite deposits with associated hydroelectric sites are favorable factors which may aid future development, particularly if there are important postwar changes in aluminum production in other parts of Europe.

Spain. Spain has been a minor aluminum producer since 1927, when a reduction unit was established at Sabinanigo, Huesca province (Figure 6). Low-grade bauxite occurs in several places, including the provinces of Asturia and Catalonia, but it is used only for the manufacture of aluminum sulphate and refractories. Ore for aluminum production is imported, chiefly from France. These imports ranged from 5,000 to 8,000 tons annually prior to the civil war in Spain.

Spain's domestic requirements for aluminum are small and the production has been only 1,000 to 1,500 tons per year. Conditions do not particularly favor the industry and production has been maintained under a high protective tariff on aluminum imports. Reduction operations ceased early in 1937 with wartime damage to the plant. The damage was slight, however, and aluminum was again produced in the spring of 1938.

Sweden. Sweden established aluminum production with the construction of a reduction unit at Mansbo, province of Dalarna, in 1934. The annual capacity of 1,800 to 2,000 metric tons of crude metal was expected to supply domestic requirements. Previously aluminum was imported, chiefly from Norway. Requirements increased, however, and imports continued. In 1937, 1,858 tons of aluminum were produced and 2,905 tons were imported. In 1938 the imports were 4,678 tons, meeting approximately 70 per cent of the requirements. The production capacity was increased 80 per cent in 1940.

Early in 1942 a plant to supply alumina to the Mansbo reduction unit was put into operation at Kubinkenborg on the Baltic coast. Since bauxite was no longer available, andalusite, a by-product of the Boliden gold mines containing 35 to 40 per cent alumina was to be used for ore. Because of its high silica and low alumina content, andalusite has not been able to compete with bauxite as an aluminum raw material when the latter is available. The plant was therefore designed for later conversion to the use of bauxite. In addition to meeting the alumina requirement of the Mansbo reduction unit, the Kubinkenborg plant also has facilities for the complete manufacture of aluminum. The combined capacity, including that of Mansbo, is for 6,000 tons of aluminum produced from andalusite or 8,000 tons from bauxite. The actual annual output has been reported as 4,000 metric tons. In spite of the impurity of the ore, the aluminum produced from it in Sweden has a high purity.

Hungary. In addition to her huge bauxite mining and exporting activities, Hungary has recently developed aluminum production. Originally designed to meet the increasing domestic requirements, later plans for the industry pointed to surplus production for ex-

port. An alumina plant was constructed at Magyarovar on the Budapest-Vienna railway line near the Austria-Slovakia border in 1933. Bauxite was supplied from the nearby Gant district and the alumina was reduced to aluminum at the electrolytic plant which began operations at Csepel, south of Budapest, in 1935. The combination of a large supply of alumina from Magyarovar and relatively cheap electric power generated on the site from lignite-fired steam made the production of aluminum feasible. In addition, the infant industry was protected by an import duty levied on aluminum and aluminum alloys in 1935. The alumina plant at Magyarovar had a capacity of 15,000 tons in 1938, considerably greater than the requirements of the Csepel unit which produced 1,500 tons of crude metal during that year. This was an increase from 900 tons in 1936 to 1,200 tons in 1937. Plans to double the capacity of the Csepel unit were reported in 1938.

A second aluminum reduction plant began production near Tata, 40 or 45 miles west of Budapest in 1939 (Figure 6). Plans included doubling the original capacity of 1,000 tons by the middle of 1940. Alumina is available by water from the Magyarovar plant. A third reduction plant with an associated alumina plant was planned for completion before 1942 in the northern Bakoney Forest area. This combination was to be able to produce 20,000 tons of alumina and 10,000 tons of crude metal. Bauxite was to be produced in the vicinity and electricity to be furnished from an associated 250 million kw. steam plant erected at the same time.

The development of aluminum production in Hungary occurred immediately prior to and during the early years of the war in Europe and a great deal remains to be seen as to its success. The planned capacity for production was considerably beyond the domestic requirements and the ability of Hungary to participate in world aluminum markets is not yet assured. Large quantities of high-grade and low cost bauxite are available. Water transportation is available in much of the area. Electric energy generated at lignite-fired thermal installations apparently is not quite so low-cost as is hydroelectric power. Marketing difficulties may add to the problems to be faced. Adjustments in world markets during the postwar period may favor the bauxite producing countries such as Hungary and Yugoslavia, although this would be contrary to earlier trends giving countries with abundant hydroelectric power the advantage.

TRADE IN BAUXITE AND ALUMINUM

BAUXITE

Several of the bauxite mining countries of Europe produce little or no aluminum, but export large quantities of ore. Other countries have large reduction industries but mine no bauxite. Since bauxite mining centers in southern Europe, and aluminum production focuses more on central and northern Europe, there is a very considerable international movement of bauxite.

Some two and one-half million tons of bauxite were mined annually in Europe during the decade ending in 1940. Approximately one-half of this amount was consumed in the mining countries. The remaining half was exported, practically all of it to other European countries. In total tonnage Hungary was the leading European exporter of bauxite. The average annual output of bauxite mines in Hungary during the

five-year period from 1934 to 1938 was almost 360,000 metric tons. Of this, 83 per cent was exported, almost all of it to Germany (Figures 2 and 10). France was second in total exports, with more than 292,000 tons, although this was less than one-half her total output. Yugoslavia exported 224,000 tons, the same proportion of her total output as Hungary. In terms of the percentage of total production exported, Greece led all European bauxite mining countries, because her total mine output was exported. Italian exports averaged 91,000 tons, approximately 35 per cent of the output.

Germany stood well above all other European countries as an importer of bauxite during the half-decade ending with 1938. Her imports were twice as great as all other European bauxite importers combined, averaging more than 862,000 tons. This situation resulted from Germany's enormous expansion of aluminum production as a measure preparing for war, plus her exclusive dependence on imported ore. German imports were approximately 300,000 tons annually during the first half of the 1930's, but increased from 326,464 metric tons in 1935 to 1,313,152 tons in 1937 and 1,184,647 tons in 1938. Every bauxite producing nation of Europe except the Soviet Union contributed bauxite to Germany's aluminum industry (Figure 10). These included Hungary, Yugoslavia, Italy, France and Greece. In addition 150,000 tons annually were obtained from the Netherlands Indies from 1936 to 1938.

Although Germany dominated the bauxite importing field in Europe, other aluminum producing countries were equally dependent on imported ore. In decreasing order of imports these included the United Kingdom, Norway, Switzerland, Sweden, and Spain. Their total requirements, however, were considerably less than Germany's. More than half the British requirements were obtained from France, with lesser amounts from British Guiana and Greece. Norway obtained bauxite from Greece, France and the United States, while Sweden's limited requirements were met with imports from France and the United States. Switzerland imported from neighboring producers, chiefly France and Italy. Much of Switzerland's aluminum raw material imports were in the form of alumina, also obtained chiefly from France and Italy. Norway also imported some alumina.

ALUMINUM

Since the aluminum producing countries are in the main also the consuming countries, there has been much less movement of aluminum than bauxite across international frontiers. This is true of other parts of the world as well as in Europe. Norway and Switzerland have been the chief commercial producers of aluminum in Europe with surpluses for export. Neither has bauxite, but largely because of available hydroelectric energy, each has developed an industry which produces in excess of domestic requirements. Before the outbreak of war, Norway supplied crude aluminum to meet the limited requirements of several of the smaller European countries. Notable among these were Belgium, Denmark, Czechoslovakia, Poland and Sweden. Some was also exported to Germany, the United Kingdom, the United States, Soviet Union and Japan. Swizerland similarly supplied small amounts of aluminum to Germany, the United Kingdom, Belgium, the United States, Japan and others.

OUTLOOK

A great many factors in several possible combinations may affect the future of the aluminum industry in Europe. The present situation is far too complicated and uncertain to permit accurate forecast of developments. Several trends which were in evidence during the decade preceding the outbreak of war, however, give some indication of the probable future situation.

The foremost of these trends was the very pronounced increase in production capacity and output of crude metal which began in 1933 and which continued into the war period. Accurate statistical data of the actual wartime production are not available, but the trend was definitely upward during the years for which official statistics or reliable estimates are available, and numerous planned additions to existing facilities were reported in 1939 and 1940. This increased output was by far the greatest in Germany, whose production rose from 18,300 metric tons in 1933 to an estimated 240,000 tons in 1940, a twelvefold increase. The increase occurred in all other producing countries, but to a lesser extent. The total European output rose 441 per cent during this period.

Because the normal growth of aluminum reduction was artificially stimulated during the past decade, it seems logical to expect a marked decline in output in the postwar period. With the damage to the facilities during the war, the decline has already begun. Also, the greatest expansion occurred in Germany whose capacity is certain to be severely curtailed for several years and may possibly be removed or destroyed entirely as a control measure.

A second probable change in the aluminum situation of postwar Europe is in the distribution of production. A radical reduction may be expected in Germany and possibly some curtailment in Italy, particularly if the control of Istrian ore should be lost. Wartime production in Great Britain and other areas which lost access to bauxite declined radically and may be expected to increase very soon. A relatively recent event in the European area was the establishment of aluminum production in Yugoslavia and Hungary, and the planned production in Greece. An increased production in the former and establishment of the industry in the latter is not improbable. Their domestic metal requirements will no doubt increase and their position in world aluminum markets may be enhanced. If adequate supplies of coal become available to France in the postwar period it seems entirely possible that French aluminum will enter more and more into world markets. The limiting factor here will probably be available hydroelectric energy.

A shift in the producing centers occurred in the Soviet Union during the war, with emphasis on the Ural Region. At least in the near future and possibly permanently, Soviet output will originate chiefly from this region. Ural bauxite is superior to Tikhvin ore and hydroelectric power is available in greater quantities in the Urals (at least until the reconstruction of the Dnepr dam). The distance and transportation factor seems to favor production of aluminum in the Urals, even if fabrication of aluminum products is done in other parts of the country.

TURNING OF TIRNOVO

George D. Hubbard

TIRNOVO, spelled Tirnovo as a concession to our English tongues which have difficulty rolling the three consonants with no vowel among them, is a small city in the province of the same name, central in Bulgaria east and west and well north of the center. It is on the Yantra River, a right bank tributary of the lower Danube, and is about midway between the great river and the Balkan Mountains.

Introduction

From early Christian centuries Tirnovo has been relatively important among Bulgarian centers in trade, politics, religion, architectural splendor, and wealth. The visitor today would scarcely guess its past glory, except for its ruins, but the nation holds it in great veneration as its capital during medieval centuries. It is about 125 miles east of Sofia, present capital of Bulgaria, though not on a direct railroad from that city. Its population in 1888 was reported at 11,314; it probably never had been very much larger. In 1926 it had 12,802 people, and in 1934, 14,100. Throughout its long history, though small compared with modern capitals and trade centers, it has been among the large places of Bulgaria.

Immediate Locale

The Yantra River.—The Yantra River (also spelled Jantra and Iantra) flows from the Balkan Mountains northward across the Northern or Danube plateau (Balkan Foreland) of Bulgaria to join the Danube, its master river, some thirty miles above Ruschuk (Ruskub). Here is an excellent modern, as well as ancient, ferry crossing-place. At least seven of the Yantra stream heads are etching back into the mountains, one at the famous Shipka Pass (elevation 4363 feet). Two of the source mountain streams unite in the Rushica River, which enters the Yantra on the west side a few miles below Tirnovo. Because the loess-covered surface has been broadly uplifted several hundred feet without much disturbance of its nearly horizontal strata, the Yantra and several other rivers flowing in the same general direction have carved deep valleys below the plateau surface. The Yantra valley is three hundred feet deep at Tirnovo, with steep, stony bluffs of limestone and shale, and a little, level flood plain. Remnants of the upland plateau in olden days were covered with grass and devoted to grazing, but grass has given place over many square miles to wheat, corn, barley, rye, oats and recently, to thousands of acres of sunflowers. Rural villages watered by deep wells dot the uplands.

The valley walls and flood plains contain many villages and towns, orchards of plums, apples, cherries, walnut and chestnut trees, and attractive vegetable gardens as well as some of the field crops of the uplands. Climate and weather are less severe in the valleys, and many springs solve the water supply problem so the valley population is relatively greater than that of the uplands.

Apparently before the plateau was elevated, all rivers over the plateau

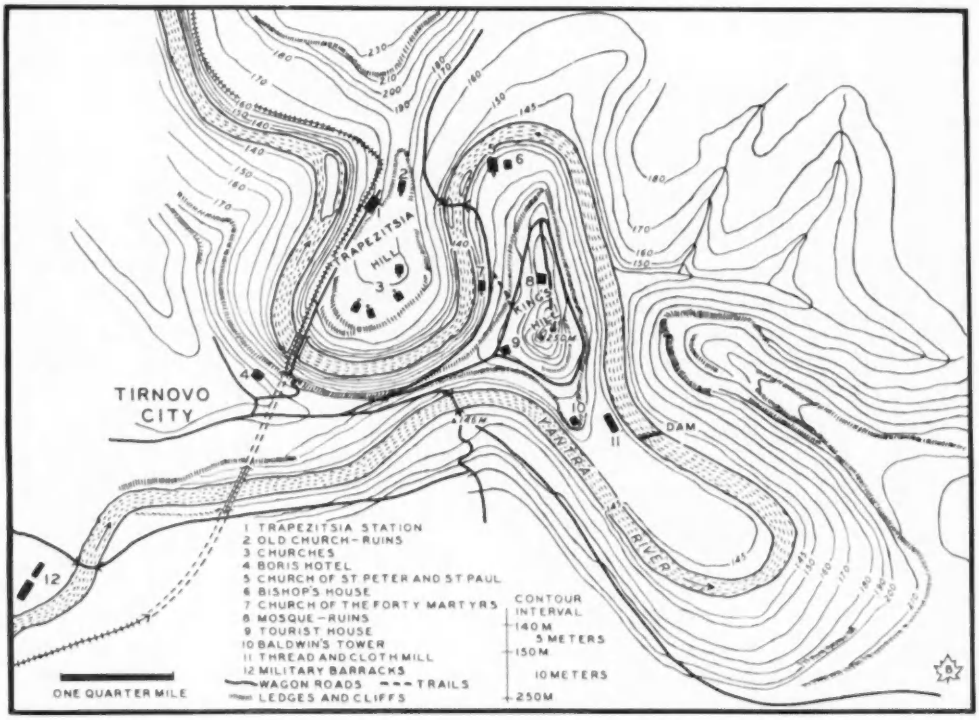

FIGURE 1.—Contour map of the incised meanders of the Yantra River and the Hills thus produced. The railroad, approaching the city from the south, passes through a tunnel, crosses the stream, takes another tunnel through a neck of land between two meanders, crosses the river again, and proceeds to the station and on down the river. Wagon roads are solid lines. Wagon and foot road from station to city crosses river on this second bridge.

(then a plain) were somewhat meandering, and now they are entrenched. At Tirnovo the Yantra has a group of striking loops of this sort (Figure 1). Necks of upland within two of the meanders have been narrowed and lowered by erosion until Trapezitsia, the western hill, is too much isolated from the upland to be reached by a road and was therefore almost impregnable to medieval attack. Tsarevitsia, the eastern or Kings Hill, while bordered by steep bluffs, is still sufficiently connected with the upland to have a road joining it to the modern upland city. The third meander, to the southeast, has completely planed off its hill and developed a flood plain of some 50 to 60 acres.

The bit of road with viaduct and bridge, that connects Kings Hill with the city, is also a part of the east-west highway (Figure 1) shown in the lower left hand part of the map coming in and sidling for a mile down the 300-foot bluff to the river bridge and climbing again to the city level. Likewise, this "bit of road" is part of the north-south road through the area. It enters the valley north of the limits of the map, crosses the river between the isolated hills, and climbs up the west bluff of Kings Hill where it joins the east and west road, soon to turn acutely eastward and descend again to the river and climb out and lead off south near the arrow on the map.

Because its trade routes must struggle so severely to get across the Yantra valley, Tirnovo would seem to have little chance to be a commercial center. Yet an intersection of routes must

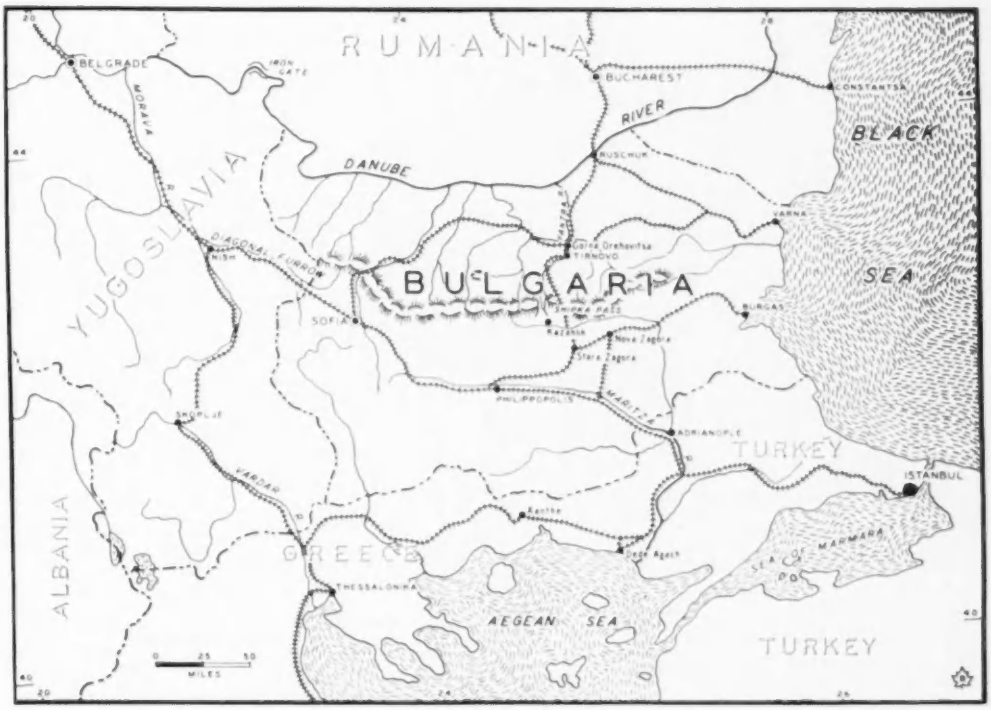

FIGURE 2.—Regional map of Bulgaria and bordering states. Present railroads approximate old trade routes.

mean transfer and exchange of goods, and the city and the hills with their rocky, ledgy bluffs were easily defended in Tirnovo's commercial prime—facts which made the town an important place.

While the river has made little obvious change in the surroundings within the 1700 years of the city's history, slow, constant steady changes are in progress. Note the arrows in the stream. The 140-meter line crosses between the hills near the Church of the Forty Martyres, and the 145-meter line crosses a few hundred feet below Baldwin's Tower. Here is a fall of five meters or nearly 17 feet in about two miles. A fall of eight feet to the mile produces a powerful stream, as both erosion and the dam for power testify. Isolation of the east and west hills and ultimately their complete planation are in the offing. From a modern military point of view its possibility of defence is weak. As a place of crossing it will be worse long before it is better.

BROADER RELATIONS

Location.—Whither did the roads lead? The east and west road through Tirnovo led from Varna on the Black Sea, across a number of valleys similar to the Yantra, joined the Diagonal Furrow at Nis (Nish) on the Morava River, and thence by connecting roads north to Belgrade and south to Thessalonika. From Varna by sea, ships carried trade to Istanbul and Odessa, while Belgrade had connections with a score of cities north and west. The north and south road connected with the Danubian highway at Ruschuk and led on north to Bucharest in Rumania, whence lines led to Poland, the Baltic, and Germany. It also led southward

up the plateau divide area toward the Balkan Mountains, over the Shipka Pass to Kasanlik in the Rose valley, to Stara Zagora, Philippopolis, Xanthe and the Aegean Sea; by sea to Athens, Egypt, the Levantine cities, Tyre, Sidon, Joppa, and others. Such commercial connections helped make Tirnovo a market place, a trade center.

Beginnings, and through the First Empire to A.D. 927.—In the third Christian century and to the seventh the Thraco-Illyrian tribal race of the country that was to become Bulgaria, was overrun by Slavonic tribes from the northeast. Even then Roman fortifications and town defended the hills, and in subsequent wars were often damaged. The Slavonians were in turn invaded in the late seventh and eighth century by Turanians, called Bulgars, from Asia, who came earlier to the Urals and lower Volga and later spread during a century over the Bulgarian hills and valleys, and gave their own name to the country. They adopted the higher culture of the Slavonians and their language, but gave them new blood, and a political organization, fused with them; and the resulting people became the Bulgarians. Their territory was rarely the same for many decades, but it always included Tirnovo.

By 802 A.D. powerful dynasties were arising and uniting the folk. The patriarch of the Eastern Church sat in several cities, Preslav, the capital, Sofia, Prespa, Ochrida, but not in Tirnovo, for it was strictly a commercial city.

Tsar Symeon, the most powerful leader, built palaces and churches at Preslav until his capital is said to have rivaled Constantinople. The first empire was at its zenith in 893–97 and declined rapidly to 927. Preslav was sacked and its wood, marble, copper, silver, and gold were carried away to adorn the new capital, Tirnovo. Preslav, some 50–60 miles southeast of Tirnovo is still in ruins.

Events from 927 through the second empire or to 1393.—For 258 years the people were under Byzantine emperors, and Tirnovo flourished as their capital and as a trade center. In 1172 a powerful man in the person of Baldwin I, Count of Flanders and Hainaut provinces along French border in Belgium came into the Near East as a knight of the fourth Crusade. He was crowned Emperor of Rumania and was given Constantinople as his portion in conquered territory. He marched on Thrace but the Greeks revolted. He depended on Kaloyan, a Tsar of Bulgaria, but in a terrific battle at Adrianople, 1205, Crusaders were defeated, Baldwin taken prisoner, incarcerated in Tirnovo, capital of Bulgars, and soon slain by the Tsar. Baldwin's Tower at the southern tip of Eastern Hill where he is supposed to have been imprisoned still stands, but not in good condition.

The Asens, Peter and Ivan, founded the second Bulgar kingdom, proclaimed the country independent of Byzantine authority and Tirnovo their capital in 1186.

They built their castle and a palace home on Trapezitsia, and their church on Tsarevitsia (east hill) just across the river from the palace. Tirnovo continued to be capital during the second Empire, which was snuffed out by the Turks in 1393. A few years after the Asens, Tirnovo renewed its religious significance and became the seat of the Bulgar patriarchate from 1235 to 1393 (although the Bulgarian church today is Eastern Orthodox, it is distinct from the Orthodox Communion). During the two centuries, 1186–1393, Tirnovo resounded with political activities, reveled in power and splendor, prospered in

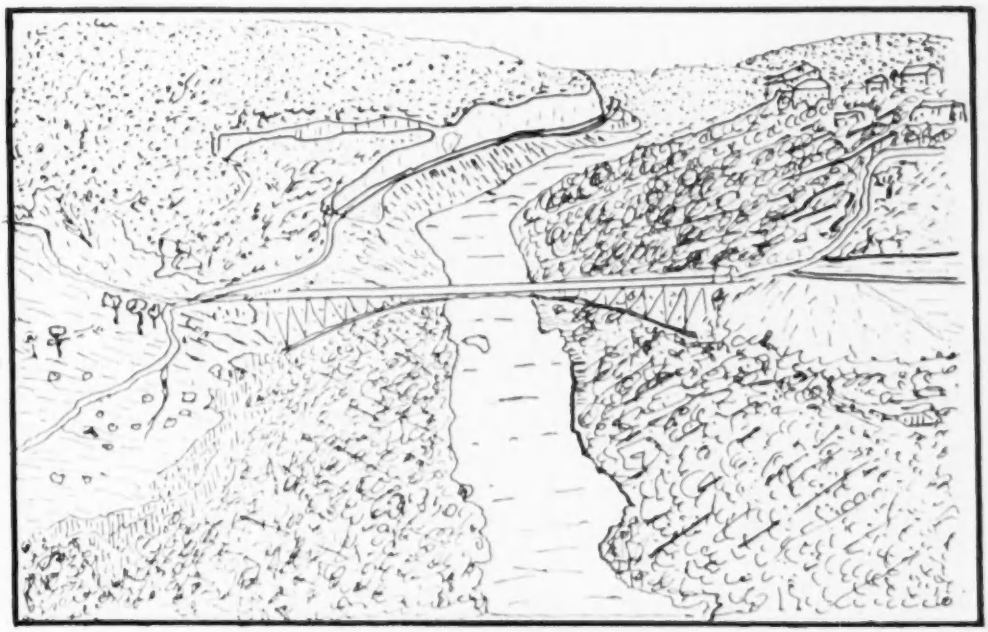

FIGURE 3.—Pen sketch from a colored postcard. Location of camera shown by 3 on Figure 1. Cliffs and forest in middle distance are called Holy Mountain and Holy woods. City in upper right corner.

trade and commerce, and rejoiced in religious leadership. Splendid buildings adorned both hills and in places extended down the slopes to the river.

Turkish rule, 1393–1878.—Internal dissensions, jealousies, and strife began to weaken the empire. Turkish invasion as early as 1340 was rolling up the Maritza valley cutting into Bulgarian territory and trade. Another host invaded farther west. Philippopolis fell in 1362, Sofia in 1382. Tirnovo fell after three months siege in 1393, Vidin in 1396, and the last remnant of Bulgar independence was swept away. For nearly 500 years Turkish blight annoyed and depressed the people.

All through Turkish rule, Tirnovo, and to a less extent several other towns, prospered by north and south trade. It was not a Turkish capital; Sofia played that role. Gradually the patriarchate was suppressed and finally snuffed out. Its commercial significance alone remained.

Turkish rule in Bulgaria began to weaken in the late 18th century. The Bulgars recovered their capital in 1767, but restored only its religious importance. For a hundred years Tirnovo continued a strong spiritual center as well as a commercial emporium. Russian influence in Bulgaria grew from 1810. In 1878 the Turks had to leave, and by that time rebuilding and reconstruction were well started in many places, Tirnovo among them.

The Modern Period.—In 1879 Prince Alexander of Battenberg took oath of office and loyalty to the constitution in Tirnovo. It had been written there the year before. It was revised there in 1893 and further modified there in 1908. Kings still go there to be crowned and Boris III, as Prince went there to be formally received into the Bulgarian Church, having been born of Roman Catholic parents.

In 1880 Sofia, a reviving old town and long time the Turkish capital, was

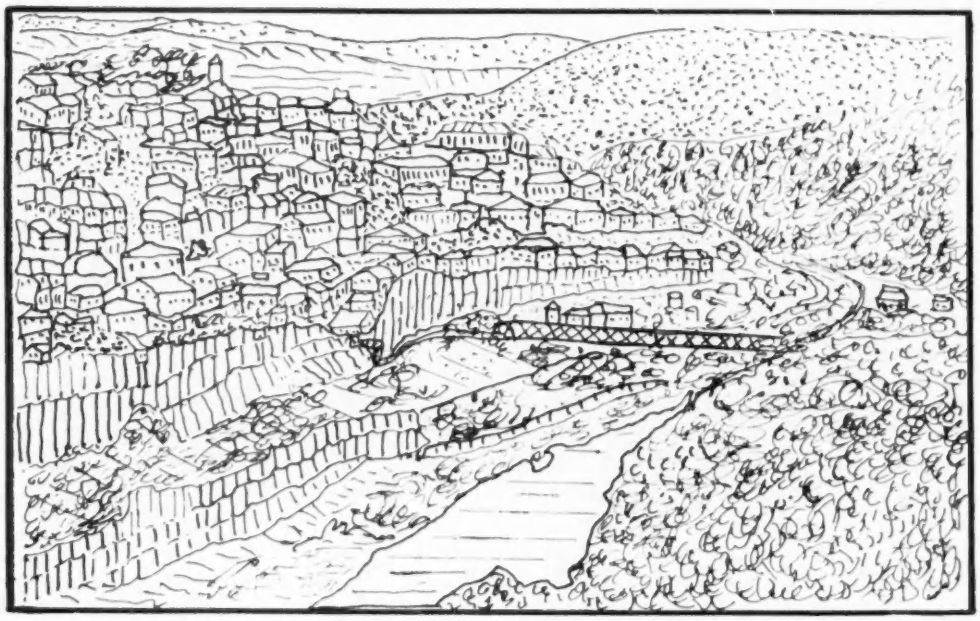

FIGURE 4.—Pen sketch from a colored postcard. Camera stood at 4 on Figure 1, thus R. R. Station is shown near middle of right margin of picture. A wide-angle lens used.

chosen to be Bulgaria's modern capital. The ruler, Alexander, built his modern palace there during the next two years. At this time Sofia had but 20,500 people, but its advantages included railroads approaching from four directions by valleys leading out in as many ways to more important distant cities. It was located near central Europe toward which Bulgarian interests were turning. Though less central than Philippopolis and less renowned in Bulgarian history than Tirnovo, it became again the capital of the new Bulgaria after World War I and has grown rapidly. In 1936 it was reported to have had 213,000 people, and at present has about 300,000. Besides being capital and flourishing trade center, it was made seat of the Bulgarian patriarchate, thus removing one more advantage from Tirnovo.

In development of railroads late in the 19th century the main east and west line, Varna to Sofia and Belgrade, was built through Gorna Orehovitsa, where incised valleys in the plateau were easier to cross than seven to eight miles south at Tirnovo. The north-south railroad, Bucharest to the Aegean, went through both Tirnovo and Gorna, but the road intersection was no longer at Tirnovo, and its last commercial strength was drained from Tirnovo.

Tirnovo today.—As a signboard to present-day significance of the ancient capital and trade and spiritual center, a well-ordered Tourist House stands on King's Hill. Near the plaza over in Tirnovo city half as far from the railroad station is Hotel Boris, less modern but convenient and comfortable for a Bulgar hostelry. By its lingering aspects of Turkish and eastern occupation it adds to the tourist's interest if not to his convenience.

West Hill has four dilapidated churches in Medieval Byzantine style and the ruins of an old church at the far north end. East Hill has Baldwin's Tower and ruins of a Turkish mosque

on top; down near the river on the west side rises the Church of the Forty Martyrs, while on the same level at the north end stands the Church of St. Peter and St. Paul, and near by, the Bishop's House. A bearded patriarch or other officer of the Eastern church is frequently met. Ruins of ancient walls, gun emplacements, palaces, and many unidentifiable structures reveal themselves at almost every turn. Down below Baldwin's Tower on the flood plain, empowered in part by water at the dam, stands a modern thread and cloth factory for which raw cotton comes from Egypt. The modern city of Tirnovo numbering 12,000–15,000 persons is well worth seeing as a sample of a 20th century Bulgarian town, but the wealth and magnificence of past centuries is nowhere to be found.

Having no modern military significance and no munition works, the city has escaped the destruction meted out freely to many other towns. During the war, a railroad was built around the loop of river encircling the plain and out of the valley eastward, again connecting Tirnovo with Varna. It will be interesting to note the effect of the new road upon the restoration of Tirnovo's commercial importance.

PETROLEUM IMPORT POLICY OF THE UNITED STATES

Olin T. Mouzon

FOR the past sixty years repeated forecasts have been made of imminent exhaustion of petroleum reserves in the United States. Leaders of the petroleum industry attribute the facture of the forecasts to the fact that our most important reserve does not depend upon the number of barrels of oil proved to be in the ground, but rather upon research and technology, "the indispensable finder, developer and multiplier," supported by a vigorous, unregimented, freely competitive industry.

Introduction

Excellence of performance of the petroleum industry during World War II gives weight to the testimony of its leaders. Domestic production and refining increased from approximately 4,400,000 barrels per day in 1941 to a peak of about 5,500,000 barrels per day in 1945, a period when military and lend-lease demand increased about 1,500,000 barrels per day and civilian consumption was cut about 400,000 barrels per day. The shift in demand necessitated the production of an entirely new range of products, which was accomplished in spite of shortage of manpower and materials and necessity of developing new means of transportation. However, it should be noted that its achievement was due in part to pre-war government sponsored methods of proration which restricted rate of withdrawal of crude and resulted in petroleum reserves sufficient to meet emergency demands, and perhaps in part to the tariff on refined petroleum products which furthered pre-war construction of domestic refineries and development of skilled technicians. In addition a strong argument can be advanced that the tariff on crude petroleum, by increasing the price of domestic crude, accelerated the discovery of domestic reserves; but the increment of these new discoveries may have been offset in part by an increased drain on domestic reserves due to the foreign crude excluded by such tariffs.

The Problem

Increased drain on domestic petroleum reserves during World War II and other domestic and foreign problems gave rise to appointment of a Special Senate Committee Investigating Petroleum Resources to study development of a national oil policy. Testimony and supporting data presented before the Committee from May, 1945 to the first part of 1946 by the petroleum industry and government agencies will be of immeasurable value in solution of many petroleum problems.

One group of such problems pertains to evaluation of the United States petroleum tariff policy in the light of our import position. In 1932 a tax of 21 cents per barrel was imposed on imports of crude and fuel oil and 2½ cents per gallon on gasoline. The tax on gasoline has not been changed, but under the authority of the Reciprocal Trade Agreements Acts a reciprocal trade agreement with Venezuela in 1939 reduced the tax on crude and fuel oil by 50 per cent to 10½ cents per barrel on an amount of crude and fuel oil equal to 5 per cent on the refinery runs in the preceding calendar year. A

reciprocal trade agreement with Mexico in 1943 provided for the same tax reduction, but without quota limitations. This agreement abolished the quota as under the "most favored nation" principle benefits accorded to one nation automatically apply to other treaty nations. The authority now exists until June 12, 1948 to negotiate reciprocal trade agreements and for reductions up to 50 per cent of the rates in effect on January 1, 1945.

Article VII (B) of the Anglo-American Petroleum Agreement, 1945, which it is proposed to extend to a multilateral agreement, states:

> "That nothing in this agreement shall be construed as impairing or modifying any law or regulation, or the right to enact any law or regulation, relating to the importation of petroleum into the country of either Government."

At this writing the United States Government has given no indication of intention to modify the petroleum tariff, even though according to the State Department the conceptual core of the United States economic foreign policy is that international commerce should be based upon free trade and private enterprise.

Thus one problem now facing the United States Government is whether crude petroleum and petroleum products should be published in trade agreement procedures as commodities upon which the Executive Branch would consider making a tariff concession under its authority to reduce duty rates up to fifty per cent. Publication gives full opportunity for hearings and presentation of information and views by any interested person before determination as to whether a tariff concession will be granted and the conclusion of a trade agreement.

To arrive at a solution to the problem it appears desirable to:

1. Establish known petroleum reserves in the United States and other major areas, and determine possibility of future extension of these reserves.
2. Estimate future demand for United States petroleum and relate it to estimated future production of United States petroleum reserves.
3. Evaluate possibilities of production of petroleum products from natural gas, coal, oil shales and tar sands.

FACTS BEARING ON THE PROBLEM

1. Known Petroleum Reserves in the United States and Other Major Areas and the Possibility of Future Extension of These Reserves.

TABLE I

CRUDE OIL RESERVES

JANUARY 1, 1945

(thousands of barrels)

Eastern Hemisphere		
Europe (excluding U.S.S.R.)		632,200
U.S.S.R.		5,735,000
Egypt		86,000
Iran		6,500,000
Iraq		5,000,000
Bahrein		300,000
Kuwait		9,000,000
Saudi Arabia		5,000,000
Qatar		1,000,000
East Indies		950,000
Other Far East		234,500
Total Eastern Hemisphere		34,437,700
Western Hemisphere		
Canada		150,000
Mexico	600,000	
Cuba	600	
Trinidad	239,000	
Colombia	505,000	
Venezuela	7,000,000	
Caribbean		8,344,600
Other South American		486,400
Western Hemisphere (ex. U. S.)		8,981,000
United States		20,453,200
Total Western Hemisphere		29,434,200
Total World		63,871,900

Source: United States reserves from "Report of the Committee on Petroleum Reserves," (Mimeographed, New York: American Petroleum Institute, February 21, 1946). Foreign reserves from C. W. Hamilton, "Foreign Oil Exploration, Production and Pipelines," (Unpublished testimony presented for Industry Committee—American Petroleum Interests in Foreign Countries presented before Special Committee Investigating Petroleum Resources June 27, 1945).

As indicated by Table I, based, like most of the evidence contained in this part, on testimony presented before the Special Senate Committee Investigating Petroleum Resources, the "proved," or known, recoverable crude oil reserves of the United States and the estimated reserves in other areas as of January 1, 1945 were 63.87 billions of barrels. Of this total, 34.44 billions were in the Eastern Hemisphere and 29.43 billions were in the Western Hemisphere, and 20.45 billions of the latter were in the United States.

Evidence, such as the foregoing, when compared with present production and anticipated demand in the United States has given rise to repeated forecast of an imminent exhaustion of petroleum reserves in the United States. So-called "proved" reserves represent oil that has been found and can be counted and is recoverable. Undiscovered oil always has upset predictions of exhaustion; and therefore the petroleum industry has said that our most important reserve is research and technology, "the indispensable finder, developer and multiplier of our natural resources."

In view of past experience and the petroleum industry's statement, possibility of future extension of crude reserves must be considered. Such consideration involves considerable guessing, and therefore the statements which follow for each of the major areas are limited to generalizations with respect to possibilities.

a. United States. In the United States, as elsewhere, maintenance of reserves with adequate productive capacity to meet demand for petroleum requires continual discovery and development of a volume of new reserves not less than the demand. According to the American Petroleum Institute, annual new discoveries and new developments in the United States for the eight-year period 1937–1944 were:

	Barrels
1937	3,721,532,000
1938	3,054,064,000
1939	2,399,122,000
1940	1,893,350,000
1941	1,968,963,000
1942	1,878,976,000
1943	1,484,786,000
1944	2,067,500,000

Except for the upward increase of 1944, such data indicate declining discovery and development rate from 3,721,532,000 barrels in 1937 to a low point in 1943, when 1,484,786,000 barrels were added to reserves. The declining discovery rate indicates increasingly difficult problems of discovery and development.

Concerning discovery and recovery of our future petroleum reserves the following statement was made by Ralph K. Davies, Deputy Petroleum Administrator for War, in an address before the twenty-fourth annual meeting of the American Petroleum Institute at Chicago, Illinois, on November 30, 1943:

> "Our experience over the past five years and the outlook for the future, as far as we can see it, suggests that whatever the reserves yet to be discovered, they will be found more slowly, with greater difficulty, and at greater expense than reserves have been found in the past. Current studies show that it is four or five times as difficult and costly to find a barrel of new reserves today as it was in the pre-1938 period."

The recent report of the American Petroleum Institute Committee on Petroleum Reserves indicates that new discoveries and new developments during 1945 amounted to 2,110,229,000 barrels, or a slight gain over 1944. Production during 1945 of 1,736,717,000 barrels yielded a net increase in reserves of 373,582,000 barrels, so that proved reserves in the United States as of January 1, 1946 were 20,826,813,000 barrels. However, only 419,984,000 of the 2,110,229,000 barrels of new reserves resulted from discovery of new pools. The balance of 1,690,315,000 barrels resulted from revisions of previ-

ous estimates and extensions to known fields.

There is wide range of opinion with respect to possibilities of future discoveries of crude oil reserves in the United States. However, there is general agreement that crude oil reserves yet to be discovered will be far more difficult and costly to find.

b. Western Hemisphere (Excluding the United States). In the Western Hemisphere (excluding the United States) vast areas remain unexplored or unproven and very significant petroleum reserves may still be discovered. Unusual difficulties in obtaining concessions, financing, and in climatic and transportation conditions have retarded exploration and development of the areas. However, it seems likely that future exploration and development will be more rapid, and that large discoveries will be made in the near future. Exploration and development already projected in Colombia and Venezuela should tap large oil potentialities, while exploration of the huge sedimentary basin of the Amazon in Brazil might reveal fields rivaling those of the Middle East.

In any event, present and potential reserves in such areas provide sources of production far in excess of estimated consumption of the areas. According to testimony of Mr. S. P. Coleman, before the Special Committee investigating petroleum resources probable excess of production capacity over consumption in the areas should provide a source of imports for the United States sufficient to supplement U. S. crude production for many years.

c. Europe. It is doubtful whether new discoveries of world significance will be made in Europe with exception of the U.S.S.R. Oil prospects in the U.S.S.R. are considered to be of enormous potentialities. It is believed that within the foreseeable future, discoveries may be made of an order of magnitude of the proven reserves of the United States.

d. Near and Middle East. The proven and indicated reserves of the Middle and Near East are situated principally in Iran, Iraq, Kuwait, Saudi Arabia, Bahrein and Qatar. Extension of reserves in those areas, presently estimated at about 26.8 billions of barrels, seems certain; no estimate can be made of their eventual magnitude. Discoveries past and future in the Middle East may exceed those in all other known producing areas. Of the present estimated reserves of 26.8 billions of barrels, the American share is estimated at about 42 per cent.

e. Far East. Exploration and development in the Far Eastern countries have been retarded by tremendous difficulties in transportation, combating disease, and operating with native populations in generally unfavorable climates. No estimates of potential reserves are available although considerable discoveries may be made, especially in China, during the next twenty years.

2. Estimated Future Demand for United States Petroleum Related to the Estimated Future Production of United States Petroleum Reserves.

a. Estimated Future Demand.

On October 3, 1945 Mr. S. P. Coleman presented before the Special Senate Committee Investigating Petroleum Resources a forecast of the trend of petroleum requirements in the United States over the next twenty years as developed by an Industry Subcommittee of Dr. R. E. Wilson's main Committee on Petroleum Requirements. Since it is impossible to predict the consumption of petroleum as far ahead as 1965, trends of requirements were forecasted as indicated by past experience adjusted

for probable changes considered in the light of certain basic assumptions.

The assumption was made that there would be no changes in the past trend of petroleum prices. No attempt was made to define variations which will inevitably occur in the business cycle; instead, a long-term trend was indicated against an economic background of high industrial activity, uninterrupted by depressions. Since the estimates were to be compared with estimates of crude availability, this basis was deemed to be sufficiently high to insure a sound approach to the measurement of the adequacy of supply.

Table II presents a summary of the United States daily average domestic and export petroleum demand for the 1947–1965 period as forecast by the Industry Subcommittee.

TABLE II

UNITED STATES DOMESTIC AND EXPORT PETROLEUM DEMAND

1947–1965

(in barrels)

Period	*Daily Average Domestic Demand*	*Daily Average Export Demand*	*Total Daily Average Demand*
1947.....	4,395,000	266,000	4,661,000
1948.....	4,650,000	.....	.....
1949.....	4,835,000	.....	.....
1950.....	4,955,000	123,000	5,078,000
1951–1955....	5,110,000	58,000*	5,168,000*
1956–1960....	5,455,000	40,000*	5,495,000*
1961–1965....	5,735,000	27,000*	5,762,000*

*Applies to last year of period.

Source: Compiled from S. P. Coleman "Statement of S. P. Coleman on Petroleum Requirements," (Mimeographed testimony presented before the Special Senate Committee Investigating Petroleum Resources, October 3, 1945).

Table III presents daily average domestic demand shown in Table II by individual products, and in total, for 1939, 1941 and the 1947–1965 period, together with certain pertinent data as to important factors affecting the forecast.

Estimated export demand shown in Table II is based on the prediction that over a period of time United States exports will decline to relatively small volume composed principally of specialty products, a conclusion drawn from the fact that actual and potential oil supplies in foreign areas, particularly in the Eastern Hemisphere, are so large as compared with possible future consumption that more than an adequate supply to meet consumption can be taken for granted.

b. Estimated Demand Related to Production. In relating demand to production of crude petroleum it is common practice to compare estimated demand with proven reserves plus possible future discoveries. In any such comparison it should be well understood that even if it were desirable or necessary, it is not always technically possible or economically feasible, to produce all reserves in the span of years indicated by relating demand to reserves. It should also be noted that extent to which petroleum products can be made available from crude oil depends not only upon volume of oil yet to be discovered but also upon solution of increasingly difficult problems of discovery, development and refining operations. The American Petroleum Institute's Committee on Petroleum Reserves had such factors in mind in its note of warning in the February, 1946 report to the effect that today's oil can be recovered only over a period of many years and at gradually declining annual rates.

In summarizing the petroleum industry's position with regard to possibility of meeting the estimated United States domestic demand for the period 1947–1965, Dr. Robert E. Wilson stated:

> "The future rates of production of crude oil in the United States are difficult to predict with accuracy because they will depend on many variables, such as price, good or bad fortune in discovery, the development of new methods of finding oil, government policy regarding taxation and public lands, etc. In

general, however, it appears that under favorable conditions for crude production the ability of our domestic industry to produce crude will probably for the next five years—and possibly for the next ten years—nearly equal the lower range of probable demand and will make possible a substantially self-contained domestic industry, if that should be deemed desirable. On the other hand, under a less favorable combination of conditions affecting domestic crude production there will be an increasing gap between domestic production of crude petroleum and the domestic demand for petroleum products. It is conceivable (though in my opinion not probable) that, under a combination of high demand and low production, this gap between our domestic production and our domestic demand might exceed a million barrels per day during the last five years of the twenty years which we are considering."

However, to the foregoing estimated United States domestic and export demand for petroleum must be added a safety factor to cover military requirements in the event of future war. In the War Department's testimony before the Senate Special Committee Investigating Petroleum Resources it was pointed out that certain undetermined military and indeterminate technological factors, plus added uncertainty as to when war may recur, its extent and who the enemy might be, make it utterly impossible to estimate intelligently the petroleum requirements for a possible future war. However, it was further stated that it was a safe assumption that—unless a practical substitute was developed—petroleum requirements for any future World War would be far greater than those in World War II.

TABLE III

PREWAR, EARLY POSTWAR AND LONG-TERM FORECAST OF TREND OF PETROLEUM REQUIREMENTS IN THE UNITED STATES
(figures in thousand barrels per day unless otherwise indicated)

	Prewar		*Early Postwar*				*Long-Term*		
	1939	*1941*	*1947*	*1948*	*1949*	*1950*	*1951–55*	*1956–60*	*1961–65*
Motor Fuel (Gasoline)									
Passenger cars	953	1,146	1,045	1,210	1,315	1,360	1,440	1,550	1,635
Aviation	10	30	125	100	85	100	125	175	200
All other uses	559	653	700	730	750	760	725	775	825
Total	1,522	1,829	1,870	2,040	2,150	2,220	2,290	2,500	2,660
Kerosene	166	190	202	206	211	215	215	225	230
Distillate Fuel Oils									
Home-heating fuel	265	341	462	448	488	510	538	555	565
Diesel fuels and all others	105	133	198	195	197	214	240	260	280
	370	474	600	643	685	724	778	815	845
Residual Fuel Oil	895	1,055	1,125	1,138	1,147	1,142	1,160	1,200	1,240
Lubricants									
Automotive	34	39	41	43	45	46	48	51	53
Industrial	31	44	44	46	46	46	49	54	57
Total	65	83	85	89	91	92	97	105	110
All Other Products and Losses	355	440	513	534	551	562	570	610	650
Total All Petroleum Products	3,373	4,071	4,395	4,650	4,835	4,955	5,110	5,455	5,735
Memoranda:									
Average Number Passenger Cars in Use									
Consumption per car barrels	25,036	27,382	25,800	28,000	30,000	31,500	34,000	37,500	40,000
Year	13.9	15.3	14.8	15.7	16.0	15.8	15.4	15.1	14.9
Average Number Oil Burners in Use									
Consumption per burner barrels	1,749	2,243	2,850	3,175	3,475	3,750	4,000	4,400	4,800
Year	57.8	56.8	51.5	51.4	51.2	49.5	49.0	46.0	43.0
Federal Reserve Board Index of Production	108	162	161	172	175	170	175 (High Business Activity)	188	200

Source: S. P. Coleman, "Statement of S. P. Coleman on Petroleum Requirements," (Mimeographed testimony presented before Special Senate Committee Investigating Petroleum Resources, October 3, 1945), page 20.

Since military and lend-lease demand during World War II reached a peak of about 1,500,000 barrels per day and military requirements during peacetime are estimated to range between only 240,000 to 290,000 barrels per day, it would be a conservative assumption that in another major war during the next twenty years, demand for petroleum products might be increased to such extent that the gap between domestic production of crude petroleum and demand for petroleum products might be in the magnitude of two or more million barrels per day. And according to the War Department:

> "Moreover, if such a war comes, the time available for mobilization of our maximum effort may be measured in weeks instead of years, in which case time for construction of refineries or extensive development of oil fields would be lacking. Such assumptions properly emphasize our real need for proved reserves of petroleum vastly greater than those now in our possession, and development providing potential crude oil production sufficient to meet any possible emergency."

3. *The Possibilities of Production of Petroleum Products from Natural Gas, Coal, Oil Shales and Tar Sands.*

Production of part or all of our domestic petroleum requirements from sources other than natural crude oil is quite possible today from a technological viewpoint but, with exception of synthesis of natural gas, is severely limited by factors of prohibitive costs of construction and operation of necessary plants and facilities. The following paragraphs deal separately with the principal methods of producing synthetic products and indicate clearly that possibilities of such production do not offer means of closing the gap between estimated demand for United States petroleum and estimated production of domestic crude.

a. Natural Gas. Recently developed processes make possible production of a substantial amount of motor fuels by synthesis of natural gas. Production has begun and may be expected to increase. It is estimated that approximately 30 per cent of our pre-war gasoline demand could be met from synthesis of natural gas by segregating about one-third of proven gas reserves for this purpose. However, even such intensive future development would not meet estimated deficit in supply in a next major war.

b. Coal. Synthetic production of petroleum products from coal has been most highly developed in Germany although considerable research and development has been, and is being, carried on in England, United States and other countries. All types of petroleum products can be produced by the Fischer-Tropsch or Bergius Hydrogenation processes using low quality coals of which the United States has enormous reserves sufficient to last, literally, for centuries. However, cost forms the limiting factor on production of petroleum products from coal. At present, construction of large scale synthetic oil plants involve an enormous capital outlay if appreciable output be desired, and cost of producing gasoline would be about two to four times present cost of production from crude oil. It is obvious that no commercial organizations could or would undertake such projects at this time. Moreover, several years would be required to design, construct and put large synthetic plants into operation so that the production possibilities of oil from coal do not, at present, solve the problem of assuring an adequate supply of petroleum to the nation for another war.

c. Oil Shales and Tar Sands. Large deposits of oil shales in the Western states and of tar sands in Canada present other means of obtaining petroleum which might be necessary to meet demands for war or peace in the foreseeable future. However, present processes for

extracting oil from oil shales and tar sands call for enormous outlays of capital and result in a product with materially higher cost than in the case of crude oil. Thus at present commercial development of oil shales and tar sands in the Western Hemisphere is impracticable. It remains to be seen whether technological improvements can place oil from these sources in competition with crude petroleum. In another major war under economic conditions approximating those of the present, it would be impossible to obtain sufficient petroleum supplies from oil shales and tar sands except after several years of construction and development. Consequently, long range possibility in oil shales and tar sands does not affect present necessity of securing additional safe sources of crude petroleum.

The preceding conclusions agree with those presented to the Senate Special Committee Investigating Petroleum Resources by the industry committee which regarded the production of petroleum products from natural gas, coal and oil shales as a very long range alternative on which industry is not likely to spend the large sums required for large scale pilot plants or semi-commercial units.

CONCLUSIONS

1. Sections 1 and 2 of Part III set forth estimated world petroleum reserves by areas, discussed possibility of extension of such reserves, related domestic reserves plus estimated future domestic discoveries and production of crude oil to demand during peacetime and a possible future war, and set forth the conclusion that there will be a gap between domestic production and demand increasing to a possible one million barrels per day during the last five years of the period 1947–1965. In a major war in the period estimated domestic production might not meet demand by two or more million barrels per day, and this deficit in domestic supply must be met from other sources.

2. Section 3 of Part III discussed possibility of production of petroleum products from natural gas, coal, oil shales and tar sands, and drew the conclusion that estimated deficit in domestic supply cannot be met from such sources under present economic and technological conditions.

3. Therefore the gap between estimated demand and domestic production of crude oil and synthetic products will have to be filled by imports.

RECOMMENDATIONS

1. *Crude Petroleum*

a. In view of the preceding conclusions it is recommended that crude petroleum should be published in trade agreement procedure as a commodity upon which our government would consider making tariff concessions.

b. It is recommended that in negotiation of tariff concessions, priority be given to such concessions as will promote importation of crude petroleum from Western Hemisphere sources so that they may be developed in time of peace and made available in peacetime and in the event of war. The basis of the recommendation is that information presented in Part III, Section 1, and in the testimony before the Special Senate Committee Investigating Petroleum Resources indicates that the Western Hemisphere, outside the United States, has sufficient proved and potential reserves of crude oil to supply future estimated demand for Western Hemisphere countries other than the United States and, in addition, to supply any reasonable amounts of petroleum that may be required to supplement the United States crude oil production for

many years in the future. Granting of tariff concessions on crude petroleum may have additional favorable effect of tending to lessen drain upon domestic crude reserves. It is most important, however, to remember that in another World War, the United States military forces will find it necessary to draw upon sources of petroleum outside the Western Hemisphere and this eventuality should be considered in establishment of foreign petroleum policy.

c. It is recommended that the effect of lower crude oil tariffs on discovery and development of domestic crude reserves be continuously reviewed, for low discovery costs and high production per well in foreign fields could result in depressed prices that would curtail domestic discovery and development. However, estimated increase in domestic demand for crude oil during the period 1947–1965 should tend to offset, in part, the depressing effect of tariff concessions on crude oil prices and on discovery and development of domestic crude oil sources.

2. *Petroleum Products*

a. It is recommended that the supply and demand position of each petroleum product be evaluated before it is published in the trade agreement procedure as a commodity upon which our government would consider making tariff concessions. However, in general, it is recommended that heavy fuel oils should be published in the trade agreement procedure, and the more valuable products of the refining industry should not be published in the procedure as commodities upon which this government would consider making tariff concessions. The basis of this recommendation is as follows:

(1) The general character of United States foreign trade in petroleum is to import crude oil for refining and heavy oils for fuel purposes and to export the more valuable products of the refining industry.

(2) The general character of United States foreign trade is sound from the military standpoint in that it results in: the importation of crude oil needed to balance domestic demand and of heavy fuel oil to protect possible Navy requirements, a diminution of the rate of withdrawal of domestic crude oil, and in development of domestic refinining facilities which are vital to the supply of petroleum products.

(3) Granting of tariff concessions on refined products might lead to importation of refined products which would retard development of United States refining techniques and maintenance of domestic refining capacity absolutely essential for military security.

b. For the same reasons developed in Section 1 *b.* it is recommended that priority be given to tariff concessions that will further domestic importation of heavy fuel oil from the Western Hemisphere.

SUMMARY COMMENT

Publication of recommended commodities in trade agreement procedures as commodities upon which the United States Government would consider making tariff concessions makes the matter a public issue; only after adequate hearings will a decision be made as to whether tariff concessions will be granted. This should enable representatives of the petroleum industry, in coöperation with cognizant government agencies, to work out a sound import policy. The War Department has presented an excellent

statement of such a policy, which is acceptable to the petroleum industry.

> "Conservation of our domestic petroleum reserves by the maximum importation of petroleum consistent with maintenance of a healthy domestic petroleum industry."

The policy now requires implementation.

At the hearings, the Independent Petroleum Association of America, which is composed of the independent producers of crude petroleum and a few companies whose operations include refining and marketing, probably will be the group that will most violently oppose any downward revision in duty rates. Expressed views of this important portion of the industry in opposition to the Trade Agreements Act were presented by Russell B. Brown, general counsel for the I.P.A.A., and were inserted in the Congressional Record by Hon. Daniel A. Reid on May 21, 1945. An objective and critical review is recommended of this complete statement, which contains several good points with respect to petroleum. The I.P.A.A. believed that:

1. The two following principal arguments used by the advocates of unrestricted imports are not valid:
   a. We should conserve our oil resources and use those of other nations.
   b. We should encourage trade with nations whose principal offering of commodities in world markets is petroleum.
2. The United States has two adequate lines of defense:
   a. Domestic reserves and future discoveries and production of natural petroleum.
   b. Domestic reserves of natural gas, coal and oil shales and production of synthetic petroleum products therefrom.

Recommended publication of crude petroleum and heavy fuel oil as commodities upon which the United States Government would consider making tariff concessions is based on the petroleum industry's testimony and military estimates of requirements during peacetime and a future World War which indicate that the preceding two lines of defense are inadequate. The principal argument advanced herein is that the inadequacy necessitates imports, and, therefore, the argument is not one which the I.P.A.A. has declared "not valid." On the contrary, since the I.P.A.A. declaration, Dr. Robert E. Wilson, speaking October 3, 1945 for the entire petroleum industry before the Special Senate Committee Investigating Petroleum Resources, stated:

1. "It is fortunate that we can, and proper that we should, use imports to make up the difference between domestic demand and our ability to produce at reasonable costs, but such action should not be carried to a point which will ever allow us to become mainly dependent on sources outside the country for our vitally essential supplies of liquid fuel."
2. "This statement of import policy meets with the approval of both companies which have large foreign reserves and independent producers which have no foreign reserves."

The petroleum industry spokesman has stated:

> "Developing the details of a sound import policy . . . will not be a simple task, but the general objectives are so clear that I believe the entire industry as well as the well-informed consumers can unite in agreeing to their desirability."

This sound import policy can and must be developed for petroleum is essential in peacetime, representing about 33 per cent of the total inanimate energy used in the United States just prior to World War II, and vital in wartime, accounting for approximately 50 to 65 per cent of the shipments to our military forces in theaters of operations. The first step in formulating a sound import policy is to publish crude petroleum and heavy fuel oil in trade agreement procedures.

HEMP; A MINOR AMERICAN FIBER CROP

John H. Garland

FROM colonial times to the present the place of minor fiber crops in the American economic structure has been precarious. Especially is this true of hemp, weak competitor of flax and cotton, of which the long soft fibers have long been used for twine, carpet thread, carpet yarn, sail cloth, homespuns, yacht cordage, and oakum. In the subsistence agriculture of much of early America, hemp was extensively cultivated to satisfy need for fibers, especially in regions beyond the limits of cotton growing. Hemp is harvested from 80 to 140 days after planting, depending on moisture and temperature conditions. As the nation grew, well-defined but widely scattered hemp districts developed, flourished for several decades, and then all but disappeared, only to be revived again briefly during World War II by the Hemp Division of the Commodity Credit Corporation of the United States Department of Agriculture.

Foreign Competition and Imports

Until machine methods were introduced, American hemp production was handicapped by its requirement of much highly skilled hand labor. Cutting and retting, field processes now done with aid of machinery, were then largely hand activities. Breaking, separation of fiber from the hurds, was also a hand job performed in the field. At present, it is done in a large power driven, machine equipped mill, which forms the focal point of each hemp district. A skilled hemp breaker fifty years ago could separate about 250 pounds of fiber daily. A crop of fifty acres required services of an estimated ten skilled hemp breakers for about two months. A modern mill which separates about 10,000 pounds of fiber in an eight hour day requires services of about eighty employes, both men and women.

In competition with cheap European and Asiatic labor, home producers never supplied more than a fraction of the American consumption of hemp. In Europe, the leaders were France, Italy, Austria, and Russia; whereas, China and Japan lead in Asia. Of them all, Italy produced the best grades of fiber. From foreign sources an average of about 2,000 tons of fiber was imported each year from 1850 until the close of the Civil War. Hemp imports increased tremendously during the next thirty years, reaching a maximum of over 55,000 tons in 1889, only to decline rapidly to about 4,000 tons by 1900. Although American production increased during the same period, competition with Manila hemp and cotton had reduced the use of hemp to less than 9,000 tons by 1900. For the next twenty years, imports of hemp averaged about 5,000 tons yearly, but during the ensuing decade 1920–1930 completely disappeared. American grown hemp followed a corresponding trend, to reach its lowest figure in 1933 when less than fifty tons of fiber were produced in the United States. In the last few years, before the Department of Agriculture set up the Hemp Division, the average yearly production was about 600 tons.

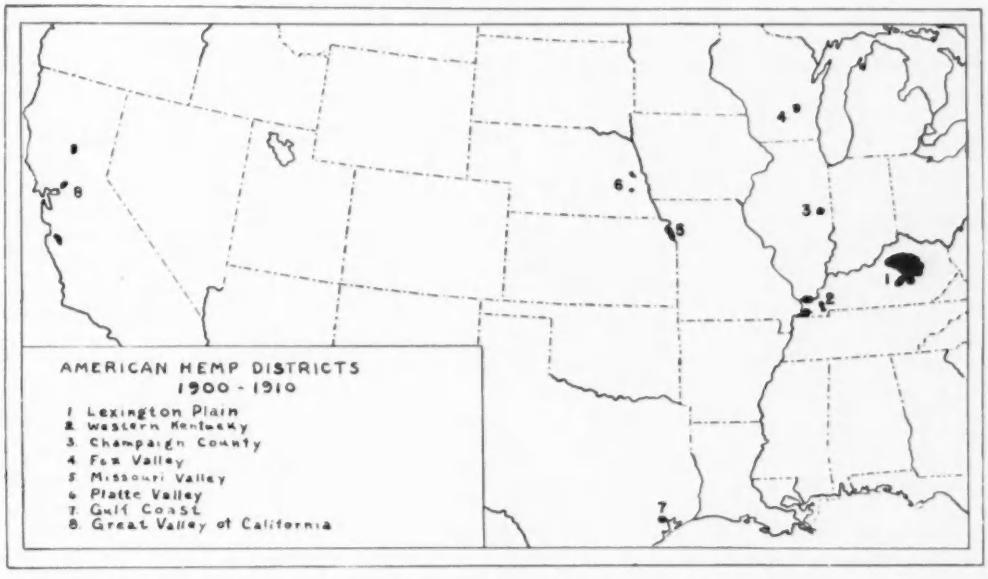

FIGURE 1.—The wide range of middle latitude conditions under which hemp can be grown is apparent from the producing districts for the decade 1900–1910. The Lexington plain of Kentucky normally produced 75 per cent of the crop during the earlier years.

HEMP GROWING DISTRICTS

Although widely scattered, American hemp districts developed in some of the best agricultural areas, and for that reason had to compete with corn, tobacco, livestock, and dairy products often disadvantageously. Decline in production resulted from curtailed acreage, not from reduced yield per acre. At the height of hemp fiber production, when the Lexington Plain of central Kentucky was the center of hemp growing, the district, together with the Gulf Plain of western Kentucky, accounts for 75 per cent of the American hemp fiber until as late as 1901. Although most of the large towns of the district were hemp markets, Lexington led them all. Lesser districts included the Platte valley of eastern Nebraska, the Missouri valley between St. Joseph and Kansas City, northern Champaign County in the corn belt of eastern Illinois, the Gulf Coast of Texas near Houston, and the Sacramento and San Benito valleys of California (Figure 1). As late as 1909, hemp was grown in the Fox River Valley of Wisconsin in cooperation with the Wisconsin Agricultural Experiment Station.

Competition from three sources proved to be so effective that the American hemp districts almost disappeared; a small area in Woodford County in the once important Lexington Plain hemp district, and a small segment in the Fox River valley of Wisconsin where the Agricultural Experiment Station had helped to develop it thirty years earlier, were all that remained in 1940. Abaca or Manila hemp from the Philippines and cotton from the southern states replaced hemp for cordage, twine, coarse fabrics, and the like. The manufacture of carpet thread, canvass, and other fabrics of cotton in several of the towns of the Lexington Plain have their roots in the old Kentucky hemp industry. More profitable use of the land for corn, tobacco, and livestock also constituted a strong factor in reducing the area of hemp districts.

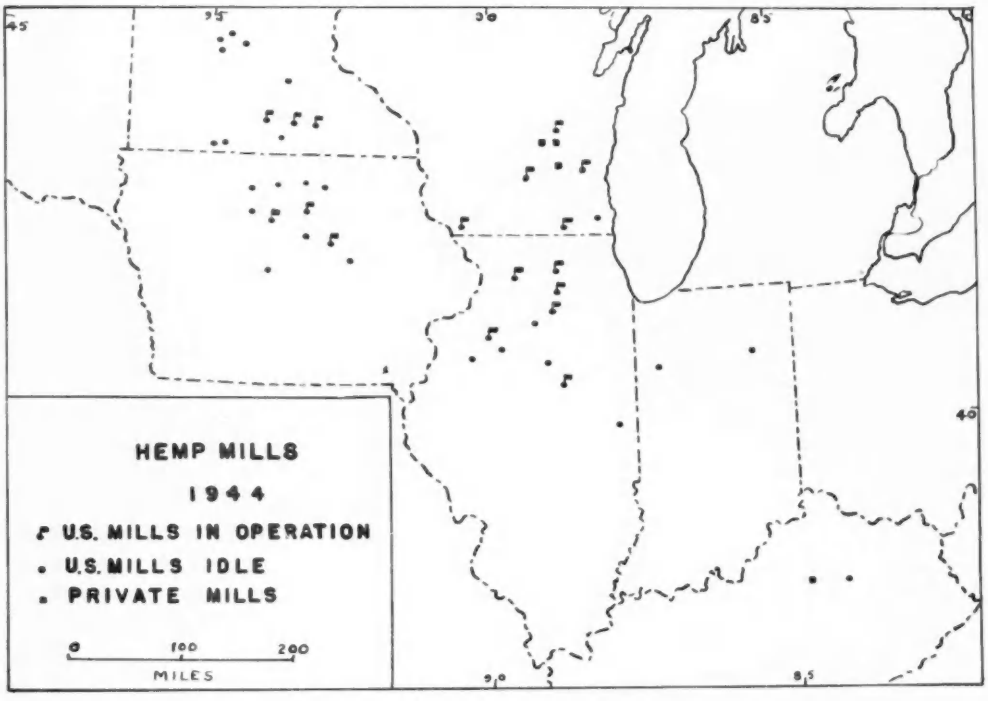

FIGURE 2.—The distribution of hemp mills in 1944 shows little relation to the earlier districts. The wartime hemp districts moved northward to northern Illinois and Iowa and southern Wisconsin and Minnesota. Only small remnants of the earlier activity are indicated by the privately owned mills in Wisconsin and Kentucky.

Loss of the Philippines early in World War II together with increased demands for cotton threatened shortage in supply of fiber for cordage and coarse fabrics; therefore a revival of the American hemp industry ensued, with the establishment of the Hemp Division of the Commodity Credit Corporation by the United States Department of Agriculture.

WARTIME HEMP REGION

The bulky stalks of early maturing staminate plants produce the longest and finest fibers, whereas pistillate plants are valuable only as seed producers. Since the bulky stalk, from seven to ten feet high, must be retted in the field from two to eight weeks, stacked for winter curing, and separated by a specially equipped mill,

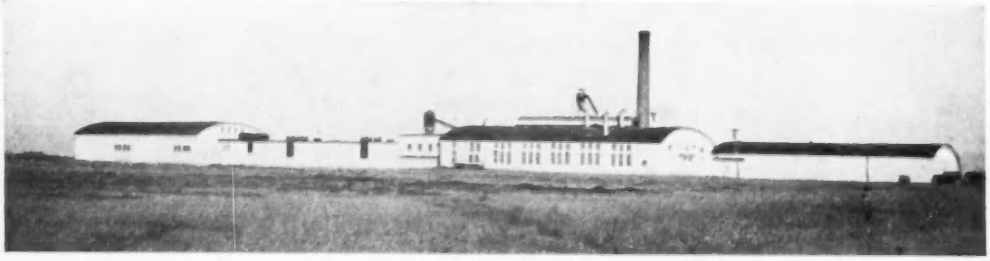

FIGURE 3.—The cement block buildings with circular roofs and the tall chimney of the power plant standardize the U. S. Department of Agriculture mills.

FIGURE 4.—Harvesting machinery of a special type designed to cut, turn, and bundle hemp straw is included in the growers contract with the Department of Agriculture. When not in use, the machines are stored on the mill grounds.

proximity to such a mill, which is therefore the grower's market, is now the essential element in a hemp district. The Department of Agriculture, thus determined the revived hemp district by locating and building forty-two mills at a cost of more than $100,000 each, and established the market by contracting with farmers within radius of twenty or more miles of each mill to grow hemp at fixed prices per grade of "straw." The mills, which have taken the place of the old hand breakers (Fig. 2), were built in or near small towns in the corn and dairy belts of Iowa, Illinois, Indiana, Minnesota, and Wisconsin, with one mill on the Lexington Plain of Kentucky. A privately owned mill at Versailles, Kentucky, and three such mills in Wisconsin which are remnants of the earlier development also operate. The northern mills are in the fiber-producing districts where the Marihuana content of the leaves is lower farther south; all hemp growers must be registered under the Federal Marihuana Tax Act of 1937 and licensed under state laws. Seed is produced in the Kentucky hemp district. Since the stalks are cut green for fiber, before the seed ripens, seed must be grown separately.

As the map (Fig. 2) indicates, twenty-five of the forty-two government owned mills were not operating in 1944 because the remaining seventeen were able to produce required amount of fiber. Acreage was determined by the War Food Administration. Of the operating mills three are in southern Minnesota, three in central Iowa, five in southern Wisconsin, and six in northern Illinois. It was announced in July 1945, that they would close and the buildings would be offered for sale after the crop then under contract had been processed. Since the straw is stacked and not processed until the following year, the crop of 1945, should be finished in late 1946 or early 1947 unless importation of fiber from the Philippines brings it to an earlier close.

RECONVERSION PROBLEMS

Because the revival of hemp growing was sponsored and subsidized by the government to meet a war need, several problems must be solved in reconversion. One is concerned with the farmers who produced the crop, and another has to do with the economic structure of the community in which each mill is located. The agricultural problem is not hard, for the farmer simply ceases growing hemp with the expiration of his contract. To many it means deliverance from a patriotic duty which,

although well paid, did not fit into a long established schedule of work.

Seeding time begins about the middle of April and continues until early July, although summer drought forms a hazard to hemp planted later than late May. Quality of fiber, largely determined by height of stalk, is directly related to soil quality. Moist, but well-drained, soils high in nitrogen are especially desirable. Fear of soil depletion with consequent tendency to use poorer soils has had some bearing upon acreage and quality of hemp produced. However, most of the nitrogen removed from the soil by the plant is in the leaves which, in the process of retting, are left in the field to be plowed under again. The pungent, ragged stalks, planted so close that cultivation is impossible and unnecessary, reach a height of seven to ten feet by mid-August. When the pollen falls, the hemp is cut by a machine. The straw lies on the ground to ret for two to eight weeks depending upon moisture conditions. Retting removes resin from the stalk and loosens the outer covering. A second machine bundles the straw, which is then transported to the mill to be stacked in the open for the winter. Lack of experience and need of extra labor at harvest time have been of especial concern to the wartime hemp grower. Spoilage of straw in the hemp yards was probably due to improper stacking. In some instances it was necessary to burn almost one-third the crop.

The agricultural program was controlled by government agencies through a Grower's Hemp contract in which the grower agreed to plant a specified acreage, to follow prescribed practices, and to sell only to the government mill. The government furnished the seed at $12.00 per bushel, specifying a minimum of 1¼ bushels per acre, and rented special harvesting machinery at $7.00 per acre, all charges being made against straw delivered at the mill. Although the government agreed to assist, the grower was responsible for additional labor without racial discrimination. German prisoners of war and displaced Japanese-Americans worked in some districts. A schedule of harvesting and deliveries was worked out and approved by the government for the most efficient use of machinery. Grading of straw was done by the manager at the mill with a guaranteed price of $50.00 per ton for the highest grade and $30.00 for the lowest. The government assumed cost of the Federal Marihuana Tax and reserved right to cancel the contract by March 1st because of circumstances beyond control of the government agency, or because of failure

FIGURE 5.—The grower agrees to deliver retted and bundled straw at the mill where it is weighed and graded by the length of the fiber. These loads have been delivered to the office for weighing.

to secure acreage for hemp sufficient to warrant operation of a mill. About 4,000 acres within fifteen to twenty miles of the mill was considered sufficient. At the height of the program one of the mills in northern Illinois, quite typical of the seventeen areas then in operation, had 4,112 acres under contract, with 189 growers coöperating in the program, of whom the farthest was forty miles from the mill. In the hemp yard there were 9,965 tons of straw from the year before.

When contracts with growers expired at the end of 1945, hemp growing ceased on the farms, and the small acreage devoted to the crop on individual farms was diverted to other uses and the labor to other purposes. Aside from the fact that cash income from this source ended, there was no other direct effect on the agricultural structure, for even the special machinery used was rented to the farmer.

On the other hand, closing of the mills will cause some dislocation in each little farming community. Mills were built near small towns or villages from which they recruited most of the labor at an hourly wage rate higher than the meager community business enterprises ordinarily afforded. Each hemp mill afforded full-time employment both winter and summer to about eighty employes, both men and women. Work at the mill consisted of separating or breaking the fiber from the hurds or refuse, a mechanized activity originally done by hand. Only 20 per cent of the hemp straw is fiber. The bulky hurds, which have no commercial value, furnished fuel for power to run the plant and were given to farmers for livestock bedding.

At the outset the hemp mills helped to drain the small communities of all available labor. They also attracted population from other communities which, in turn, encouraged expansion of local business. With termination of government activities and possible sale of the mills, new problems face each community. It is quite unlikely that private industry will be capable or even interested in trying to operate the mills to process hemp for obvious reasons. The second possibility foremost in the minds of many of the hemp-community citizens, especially those employed by the mill, is its purchase by some large industrial company and its conversion to some other use, especially one that will employ a number of people. It is

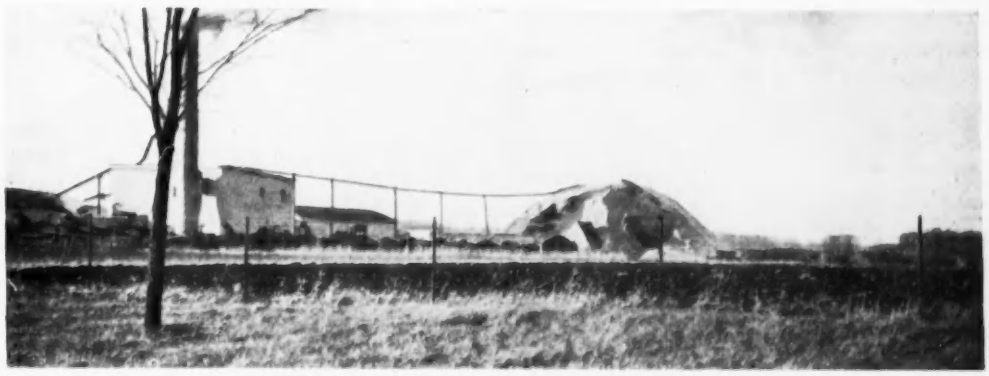

FIGURE 6.—The chief function of the mill is the breaking or separation of the fiber from the hurds or refuse. The hurds are burned for fuel in the mill and are given to farmers for stock bedding. A large hurd stack has accumulated in the mill yard.

FIGURE 7.—Bundles of retted hemp are stacked on end in the hemp yard to cure during the winter for processing the next year. Due to inexperience and improper stacking much of the first wartime crop spoiled in the stack.

probable that most mills will stand idle regardless of what disposal is made of the property. The employes must be reabsorbed in the regular economic fabric of their community.

Hemp production in the United States reached an all-time high under the government-sponsored wartime program. That the future repeat the past seems apparent. The same competitive factors that reduced hemp acreage to negligible proportions prior to World War II, are still operative. The war program for hemp, was at best only an emergency measure, and although developed at great expense, has already been abandoned. Sale of the mill will not insure continuation of the industry, which, will probably again shrink to remnants in the Fox River Valley of Wisconsin and the Lexington Plain of Kentucky.

BIRMINGHAM AND THE BLACK COUNTRY

Henry Rees

THE term "Black Country" is reserved for the metal manufacturing towns which have developed on the South Staffordshire coalfield. Birmingham to the east and Wolverhampton to the west are normally excluded from the group, though coal is present beneath them at considerable depths.

The South Staffordshire coalfield is the only important field in Britain which has not easy access to the coast; indeed, it lies practically in the centre of England and athwart the main water-parting of the country. This inland situation accounts in large measure for the extraordinary growth of canals, while difficulty of transport explains the relatively small development of the heaviest branches of the iron and steel industry. The unusual variety of the metal products of the area is perhaps related to the fact that Birmingham and the Black Country are dominated by no single market but can supply all the great conurbations of Britain.

Geology and Physical Features

The area is essentially a denuded dome, with the oldest rocks—Silurian Limestones—exposed near the centre, and the younger rocks—Coal Measures, "Permian" and Trias—outcropping in succession. The rocks have been greatly disturbed by faulting, resulting among other things in decisive eastern and western boundaries to the exposed coalfield.

The most notable seam of the South Staffordshire coalfield is the "Ten Yard" or "Thick" coal, which reaches the unusual thickness of 30 to 35 feet. Underlying a large area, this seam, together with the associated bands of limestone, has been a source of enormous wealth to the district. Outcrop of the "Thick" coal passes through Dudley and Darlaston and to the west of Bilston (see Figure 2). Farther north it becomes split into over a dozen separate seams, still totalling about 30 feet, but separated by hundreds of feet of barren strata. The ironstones are now worked out, and for the most part the "Thick" coal has been exhausted in the Dudley area. The most productive portion of the coalfield is being worked through the Triassic cover of Cannock Chase, to the north of the Black Country. Mining has also taken place beyond the eastern and western boundary faults, in the east near the Birmingham outskirts and in the west at Baggeridge Colliery, only a short distance from Woverhampton. From all sources about 6½ million tons of coal are raised annually.

The so-called "Permian" rocks, though devoid of coal, are now grouped with the Upper Coal Measures, on a basis of their fossils. They have had little significance in the industrial development of the area.

The Triassic rocks consist of Bunter and Keuper Sandstones and Keuper Marl. The Bunter Sandstones have supplied high quality moulding sands for the metal trades and have been valuable sources of water supply for the urban areas.

The chief exposure of the Keuper Sandstone takes the form of a curving escarpment, passing through the centre of Birmingham. This has had a marked

effect on the settlement of the area, owing to its water-bearing properties. Indeed, the unusual growth of Birmingham compared with the towns to the west has been ascribed to the fact that it was the nearest point to the coalfield at which a plentiful supply of drinking water was obtainable. Resistant and porous, this escarpment—known in the Birmingham area as the Keuper Waterstones—has provided attractive sites for Saxon villages, mediaeval castles and modern Birmingham suburbs. It is also an important source of building stone. At its foot flows the little River Rea, on whose banks Birmingham first grew.

East of the escarpment lies the Keuper Marl, forming a rolling lowland area, in former times supporting the Forest of Arden, and in the early iron industry providing reserves of charcoal for smelting purposes.

The most prominent feature is a ridge trending N.W. to S.E. and rising at its highest to over 800 feet. It is related to inliers of Silurian Limestone and Igneous rocks exposed in the central parts of the eroded dome. This ridge, a section of the main waterparting of England, separates the Tame headstreams, flowing to the Trent, from those of the Stour, flowing to the Severn. Parallel to the ridge is the broad and shallow valley of the upper Tame, outlined by the 400 feet contour. It will be noted how this line provides the

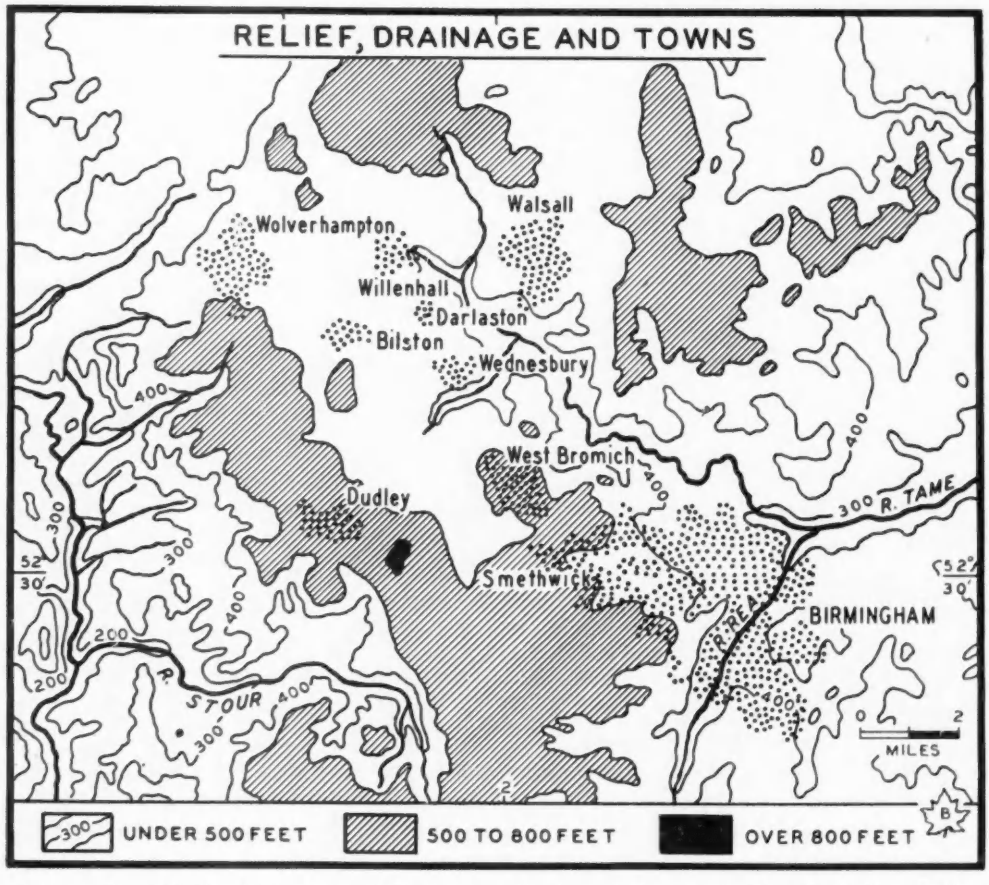

FIGURE 1.—Relationship among relief, rivers, and urban settlement, in the Birmingham "Black Country" is clearly revealed on the map. Chief rivers are marked and 100-foot contours drawn. Area over 500 feet elevation is cross-hatched, and chief urban communities are indicated by stippling.

effective limit to the dry sites suited to urban settlement in the area. The same contour in the Birmingham district hints at the existence of the Keuper Waterstones escarpment, trending N.N.W.–S.S.E. The contrast between the sluggish, mature drainage of the Tame headstreams and the swift, youthful headstreams of the Stour is apparent. The steep gradients of the latter provided suitable sites for the use of water power in the early stages of the Industrial Revolution and attracted the heavier processes away from the eastern centres. Finally it will be noticed that with the exception of Dudley, all the chief urban centres of the Black Country have developed on the relatively level topography of the coal measures, allowing easy inter-communication and ample room for expansion.

The Growth of Industry

The Industrial Revolution greatly expanded the Black Country towns, but their actual origins lie in the remote past. Perhaps the earliest record is that of Wednesbury, which claims to have been mentioned as the site of a battle of 591, recorded in the Anglo-

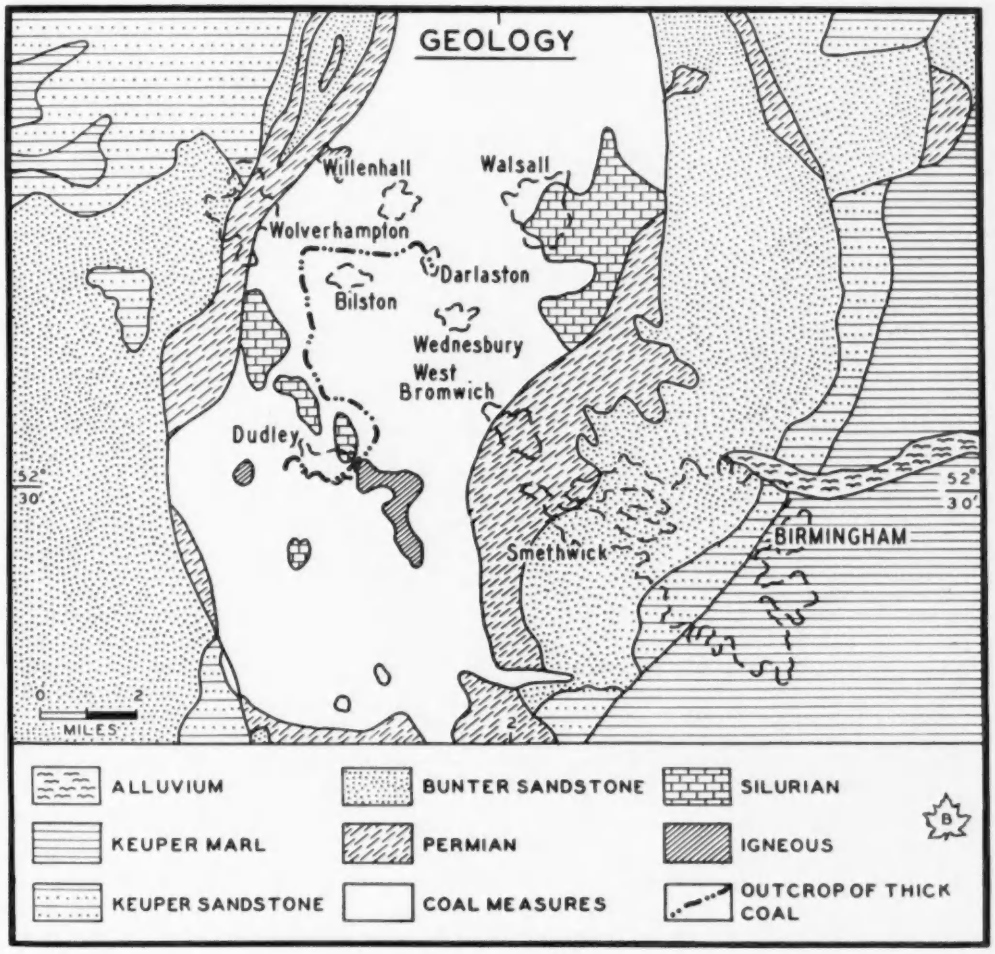

FIGURE 2.—Outcrop of the "Thick" coal of the "Black Country" is shown in relation to the distribution of the geological formations. It passes through Dudley and Darlaston, and westward of Bilston.

Saxon Chronicle. Wolverhampton is mentioned in a charter of 895, and Bilston in one of 996. Walsall was recorded as a settlement in 1004 (then "Walesho") and "Smedewick" (now Smethwick) is recorded in the Domesday Book.

Birmingham was an Anglo-Saxon settlement which had at the time of the Domesday Survey nine families only, apart from that of the lord of the manor. It had grown up at a ford point on the Rea, where Keuper Sandstone provided a firm foundation for settlement; it consequently became a market centre, developing those industries, such as iron and leather, which are needed in agricultural regions. For these the area was well suited, being close to deposits of iron ore, to timber for charcoal, to bark for tanning, and to coal deposits which replaced in later times the dwindling timber reserves. Like Manchester, Birmingham was a non-corporate town, free from gild restrictions, and therefore attractive both to inventors and to nonconformists.

A conjectural map—published 1886—of Birmingham in the 16th century shows the moated manor house, a mill on the Rea, St. Martin's Church, and the triangular market place as the chief nuclear features of the little town. On the authority of Leland, who passed through in 1538, knives and cutlery were being manufactured at that early date and a high degree of skill in the metal trades was being built up. In the 17th

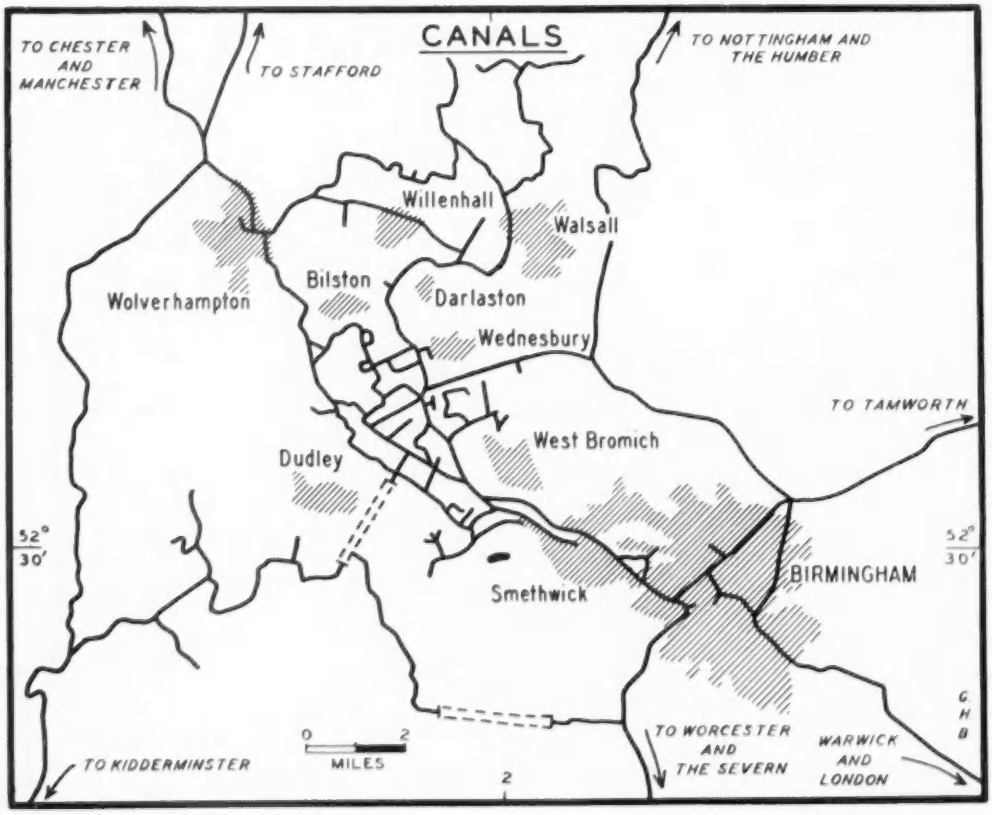

FIGURE 3.—The extensive network of canals of the "Black Country" which has developed on the coalfield, links all the chief mines, quarries, and waters with one another, and connects with the principal inland waterways of the Kingdom.

century swords and guns, buttons, buckles and metal trinkets were being produced. By this time supplies of charcoal were becoming exhausted, and with the introduction in the 1730's of the smelting of iron by coke, the iron industries were attracted westwards towards the coalfield. This trend was reinforced by the availability of water power from the vigorous headstreams of the Stour and by the convenience of this western district for the import via the Severn of ores and bar iron from Sweden. Thus the processes of cutting and rolling, being dependent on water power, became concentrated mainly in centres in the Stour valley, south of Dudley, while the finishing processes, such as the manufacture of nuts and bolts, nails and chains, became centered on Birmingham and the nearby towns.

As an example of the part played by inventors the history of the Soho Foundry may be quoted. Soho is the name of a district of Smethwick, to the west of Birmingham. Here in 1764 a small iron mill was purchased by Matthew Boulton. Ten years later he was joined by James Watt, and the Soho Foundry began producing the massive castings required by Watt's improved steam engine. The same firm was later joined by William Murdoch, the pioneer of gas lighting.

During these years the canal system was growing. Figure 3 shows the extensive network which has developed on the coalfield, with numerous side arms and branches linking all the chief factories, quarries and mines, and with

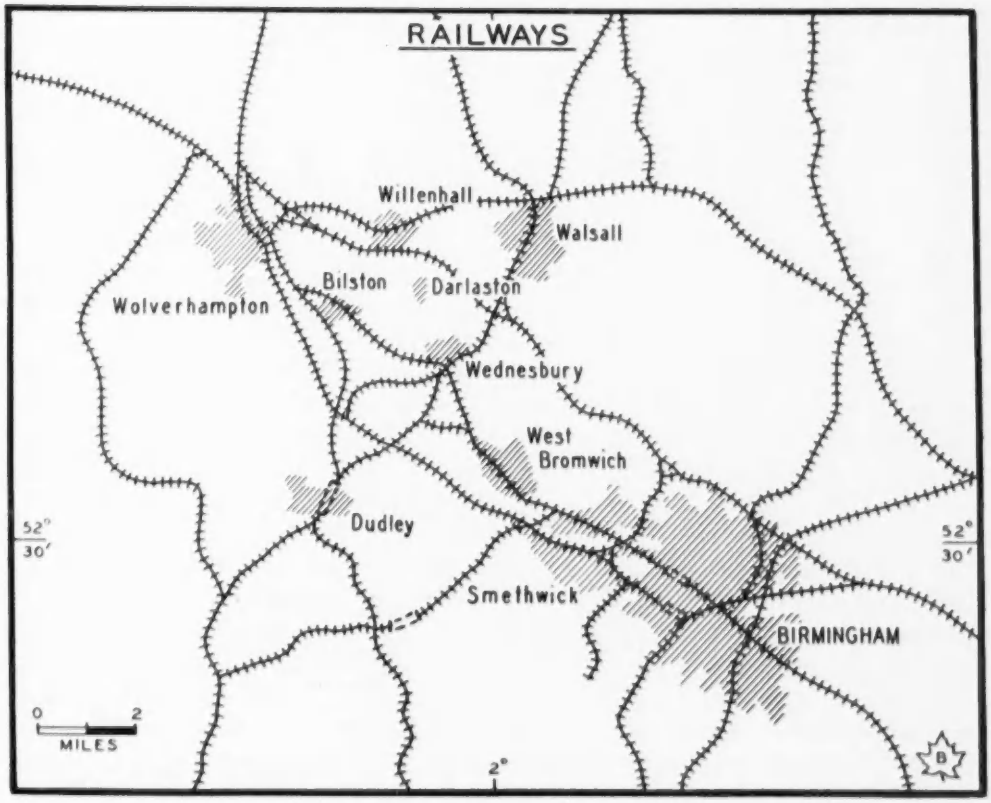

FIGURE 4.—The effective rail network of the "Black Country" consists essentially of three parallel lines which follow the trend of the upper Tame, and connect Wolverhampton and Birmingham, as did the early canals.

connections to the principal inland waterways of the kingdom. The main artery is a waterway which was authorised by Parliament in 1768 and completed in 1772, linking Birmingham with the Wolverhampton coal-producing area via Smethwick, Oldbury, Tipton and Bilston, and connecting near Wolverhampton with the Trent and Severn Canal. The waterway proved a great stimulus to industry in the area, reducing the price of coal in Birmingham by nearly half, and attracting iron works, factories, brick works and chemical works to the canal side sites. This first canal, constructed by Brindley, entailed the use of locks; but in 1829 a new and improved waterway by Telford was opened, doubling the older canal at Smethwick, dispensing with locks and connecting with Wolverhampton entirely at the 500 feet level.

The total length of the Black Country canals is estimated at 159 miles, interrupted by 216 locks. The Keuper Waterstones scarp is climbed by three flights of 13, 11 and 6 locks, and the summits of the Dudley Hills are avoided by two tunnels. For the most part the canals are narrow, accommodating only barges of 30–50 tons, and there is now little through traffic.

Figure 4 illustrates the rail network, consisting essentially of three parallel lines, following the trend of the upper Tame and connecting Wolverhampton with Birmingham, as did the early canals. There are in addition a number of transverse connections, notably that between Walsall and Dudley. The piecemeal development of English railways is illustrated by the fact that two separate companies, the Great Western and the London, Midland & Scottish, operate between Wolverhampton and Birmingham. There are thus two stations at Wolverhampton within a few hundred yards but with no connection. Smethwick possesses six stations—three of each company, while Tipton has seven.

The map shows the tunnels which avoid the Keuper Waterstones scarp; Birmingham thus benefits by avoiding unsightly railway stations in its central area. At present rail transport over short distances is irritatingly slow. It takes 30 minutes to travel by G.W.R. between West Bromwich and Wolverhampton, only some eight miles, and 25 minutes by L.M.S. from Wolverhampton to Walsall, about six miles. It is not surprising to find that the local people prefer to travel by bus.

Road passenger transport is speedy and efficient, in spite of a multiplicity of organisations. All of the larger local authorities operate their own transport services, which normally extend to the municipal boundary and no farther. In few other districts are so many diverse systems of transport to be seen in the course of a few miles. Darlaston, for example, is served by Walsall petrol buses as well as Wolverhampton trolley buses, of which it is the terminus. Wednesbury is served by both Walsall and West Bromwich buses, while all the Black Country towns are served by an independent organisation, the "Midland Red" buses.

PRESENT INDUSTRIAL CONDITIONS

To anyone new to the Black Country the 6″ Ordnance Survey map provides a striking introduction. The whole of the older western portion of the coalfield is a mass of abandoned colliery shafts. The surface is dotted by artificial ponds and lakes occupying the sites of old quarries. The sign for heath covers wide areas, and complicated curving lines of hachures indicate the positions of tip heaps and slag dumps. At intervals are marked the iron works, furnaces and foundries which complete the depressing picture. The map was

published in 1884, and even at that date it was hard to discover a single working shaft. For the most part the natural resources have now been exhausted; the exposed coalfield and the ironstone beds have been worked out; the Silurian Limestone of the Dudley area has been so quarried that only dangerous caverns survive. There remains the human factor, in the shape of the accumulated skill of centuries in the working of metals. The most striking feature of the area is the way in which industrial momentum has resulted in the survival of specialised metal industries whose existence can no longer be explained in terms of physical geography.

With this consideration in mind we may glance briefly at a few representative Black Country towns.

Wolverhampton, a County Borough of about 144,000 inhabitants, is situated beyond the western boundary of the coalfield. It contains a well marked civic centre, comprising the Town Hall, Technical College, covered markets and a shining new Civic Hall. All these are grouped around St. Peter's Church (13th–15th centuries) built of red stone and of cathedral dimensions. Adjoining is the commercial centre, spreading over several roads and including multiple stores, banks and insurance offices. The central part of the town is an industrial area containing at least 75 separate firms producing mainly small pressed steel parts for the lock-making and other metal industries. Many of them employ fewer than five workmen. The heavy industries have developed in a belt trending N.W.–S.E. to take advantage of rail transport. They comprise iron works, tool sheds, engineering, motor and safe works. Local world-famous products include Sunbeam motors, Goodyear tyres, Boulton-Paul aircraft, Courtauld rayon, Fischer ball bearings and Chubb safes.

In Walsall the predominant industries are leather and saddlers' ironmongery. The local trade directory is instructive: 35 firms produce leather bags; 54 manufacture leather purses; 22 produce bridles and 15 produce spurs. It is claimed that every conceivable article for the equipment of the horse is manufactured here, and that Walsall is the world's metropolis for harness, saddlery, and saddlery ironmongery. The town is built around a steep hill of Silurian Limestone crowned by St. Matthew's Church. From here descends the High Street, wide enough to contain the market when Walsall was a country town, but deserted by modern traffic on account of its steepness. From the top of the hill factory chimneys and red brick houses can be seen stretching into the distance in all directions.

Willenhall, some two miles distant, claims to hold a monopoly of the lock and key industry. This activity is old established, for in the time of Queen Elizabeth the town was granted the privilege of producing all the locks required for state purposes. In 1770 there were reputed to be 148 locksmiths in the town. Eighty-five years later the number had swollen to 340. Today in the town and its suburb of Short Heath there are about 200 factories producing locks of all types: mortise locks, yale locks, padlocks, locks for suitcases and locks for prisons.

West Bromwich has for long specialised in springs, in the manufacture of which there are about 30 firms engaged; there is, however, a bewildering variety of other products of this busy town, including hardware and holloware tubes, oils, colours, paints and greases, and electrical and mechanical engineering products. The town has as its chief artery the wide straight road which in the 18th century was the main coaching highway between London and

Holyhead, and which helped the town to rise to importance. In the following century, just when the coal seams farther west were becoming exhausted, new valuable seams were discovered close at hand. There are two collieries within the borough boundary.

Smethwick, the home of the Soho Foundry, has a special interest in the production of finished iron and steel goods of all types, from nuts and bolts to locomotives. The Foundry is now occupied by a firm producing weighing, counting, measuring and mixing machines, and the original Murdock gasholder is still to be seen there. Smethwick has also specialised in the glass industry, its products including spectacle and window glass, heat resisting and cathedral glass. The town furnishes aerodromes with floodlights and beacons, cities with traffic signals, and is one of the few centres in the world prepared to manufacture and equip lighthouses and lightships. It was here that the Crystal Palace was produced.

Modern Birmingham has spread far from the tiny stream whose ford point provided its nucleus. The chief value of the Rea today is that it provides a convenient drainage channel for the disposal of storm water from the city. The main streets and public buildings have spread over the high ground formed by the Keuper Waterstones scarp. Its municipal buildings include the "Old Town Hall," Public Library, Art Gallery and Museum, all facing a central square. Adjoining is the new civic centre, of clean white stone, and the Hall of Memory.

Birmingham industries display an unusual variety, though there is an emphasis on the metals, both ferrous and non-ferrous, and on the finishing processes. It holds a monopoly in England of the manufacture of pins and of tubular bedsteads. In the production of bicycles it is second only to Coventry. The manufacture of steel pens had its origin here and electroplating was a local invention. More than a thousand separate firms engage in the manufacture of jewellery, both cheap and expensive styles. It is the home of the Wolseley, Austin and Lanchester cars, and has an important electrical engineering industry. Cadbury's chocolates are manufactured at Bournville, a Birmingham suburb, and there are large numbers engaged in the production of beer, sauces, vinegar, cakes and custards. Heavy industry has developed mainly in the east, in the low-lying tracts adjoining the railway sidings; the jewellery quarter is in the northeastern quadrant, a mass of small workshops interspersed with shabby dwellings.

We may end with a note on town planning.

A fine new motor road with divided traffic lanes along which ribbon development is restricted links Wolverhampton with Birmingham, by-passing all the larger settlements. Wolverhampton has its modern municipal housing estates and an attractive plan for redeveloping the central area. Walsall has forged ahead in the provision of ring roads, and likewise has produced central area proposals. That the will to improve exists may be illustrated by a single example. Darlaston is a small township with limited resources. One passes rows of dingy dwellings, then, on the outskirts the coal mines and the tip heaps are reached. Yet there, on the lower slopes of a waste dump, the town council have planted a public garden, whose carefully tended flower beds contrast strangely with the pithead gear only a few yards away.

CONCLUSION

It has been shown that the South Staffordshire industrial area has a distinct personality. On this plateau aided by physical advantages there grew up an iron industry, in its time one of the foremost metal working areas in the world. These physical advantages have largely disappeared, yet the area has continued to prosper owing to accumulated skills; hence the apparent contradiction between the thriving industrial townships and the desolate and abandoned mines, quarries and dumps which separate them.

But the efforts of a few municipalities cannot do more than touch the fringe of the problem. Only a national body with wide powers and adequate financial resources can hope to undertake the extensive levelling and drainage needed to convert derelict land into something useful and less unsightly.

TWIN CITIES OF WATERLOO AND KITCHENER

Chun-fen Lee

THE Grand River valley of western Ontario is predominantly an urban area and clustering of urban centers characterizes the middle valley. However, the cultural landscape of the Kitchener-Waterloo urban district presents a picture of distinctive character in the region, i.e. two communities with separate centers are found twinning.

Early Period of Settlement

Most twin-cities are found in pairs of river towns facing each other. The situation of this urban district is different. Both lie in the sandy hills district—Waterloo kame moraine, and are not separated by a stream of appreciable size. They started at two separated sites about two miles apart, and their early development was almost independent of each other. The first settlement in Kitchener was made in 1802 at the site near the east bank of Schneider Creek, as shown by a triangle on the map (Figure 2). During the first thirty years of settlement, Queen, King and Frederick streets being main entrances from the surrounding country were the principal streets of the then village. Later development was mainly toward the southeast.

Settlement in Waterloo was started four years later than in Kitchener. The grist mill established beside the Beaver Creek and run by water wheels made Waterloo a business center of local importance. Progress of settlement was very slow until after 1850, for during the early period land owners were reluctant to sell their land in small lots to prospective settlers. Up to that date, most buildings were in the northern section owing to higher elevation and better drainage than in the south where swamps were common.

Before 1850 or prior to the coming of railroads there was a wide gap between Kitchener and Waterloo—north of Queen Street and south of Erb Street—owing to the intervening sandy hills and cedar swamps. Near the two points of origin, there were two swamp areas, one occupying the present site of Victoria Park and the other lying south of the Beaver Creek. According to authentic information, residents had been working to level the hills and elevate the low-lying swamps for over one hundred years in order to bring the land up to a level which could be sufficiently drained for residential or other purposes.

Influence of the Railroads

Prior to railroads, the two centers were two entirely separate organisms connected by a road, now the main street of both, with a few scattered residences between. After 1850, Kitchener has grown up as an important freight connection of the C.N.R. railway and was about thirty years ahead of Waterloo to get the railway traffic. Not until 1882 was the line extended from Kitchener to Waterloo. Kitchener was on the main line from Montreal to Sarnia, both for freight and passenger traffic. Since then, Kitchener has far outgrown Waterloo with the latter actually having become a satellite of the former. The continuation of the two independent nuclei, or commercial areas depends

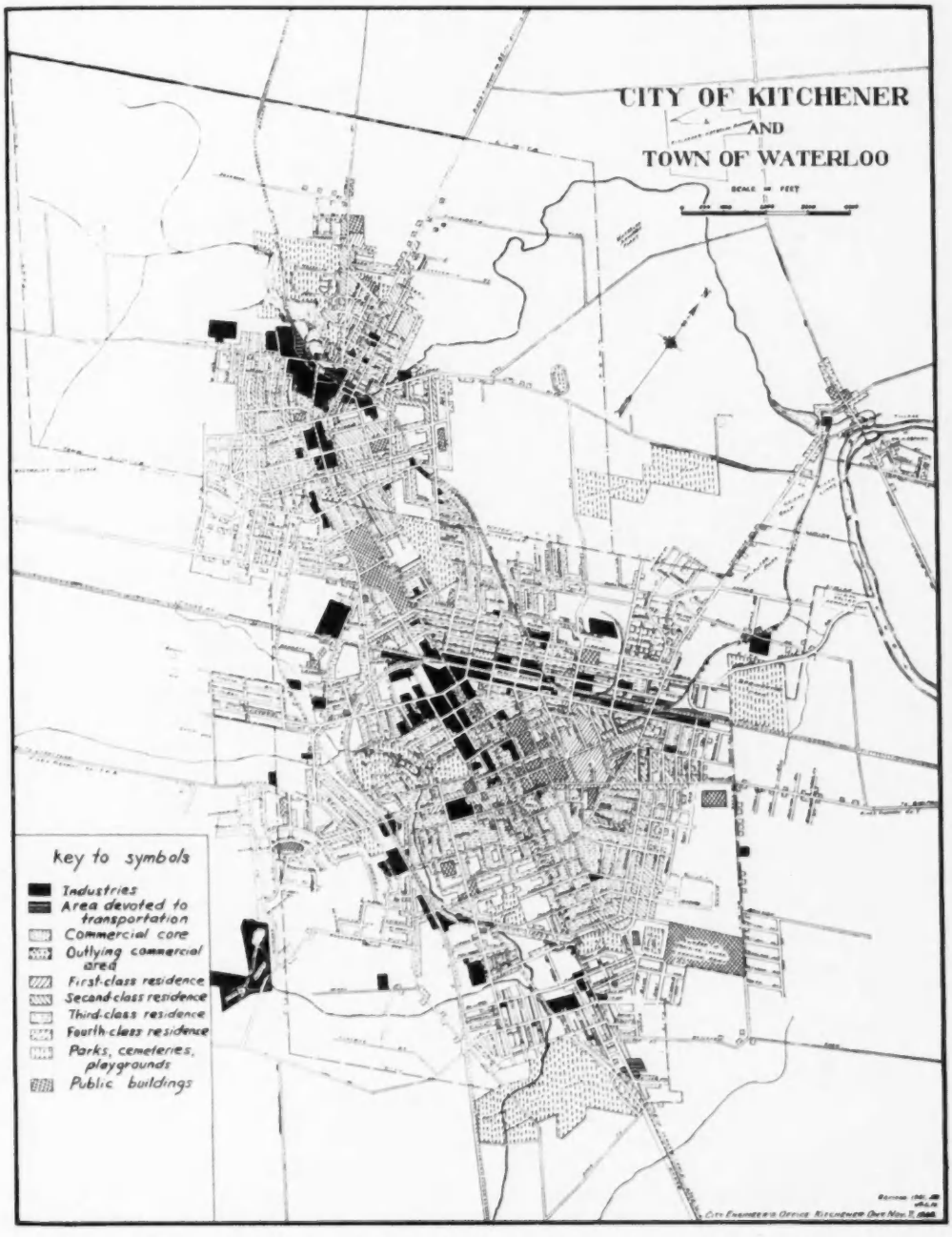

FIGURE 1.—Distribution of several types of residence and land use reflects normal conditions of adjustment of population and pattern of occupance to the character of terrain.

only upon the maintenance of two independent road centers. The extent of the immediate surrounding tributary area of Waterloo is largely in the north, while that of Kitchener is in the south.

MAJOR CONTRASTS BETWEEN THE TWO CENTERS

The chief differences are contrasts in size, industries and complexity of urban

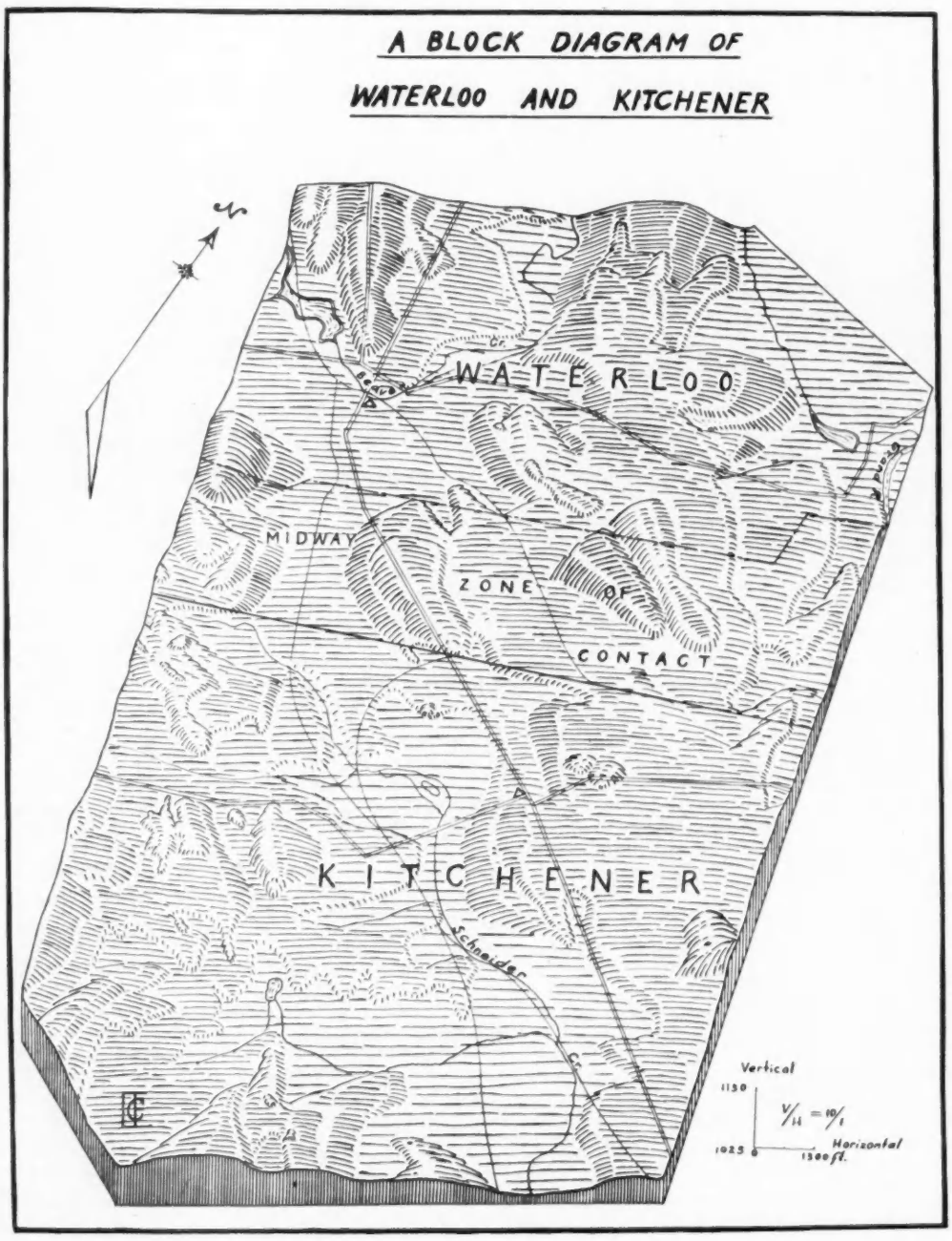

FIGURE 2.—The terrain about Waterloo and Kitchener is not level, yet it is not so rugged as seriously to affect either settlement. The pattern of growth of both communities and their interdependent relationships represent in part, adjustment to the relief.

structure. Within the respective political limit, Waterloo has a total area of 2,800 acres, Kitchener has 3,423 acres. But the latter has in places outgrown its political limit. As far as the occupied area is concerned, Kitchener is about 3.5 times as large as Waterloo.

The population of Kitchener was 35,456 in 1941, while that of Waterloo 8,968. The larger population of the former results from the period of greater industrial growth. In 1939, Kitchener had more than seven times the factory

FIGURE 3.—Commercial area of Waterloo, in general resembling a great number of middle-sized country towns and county seats in Canada and the United States.

employes and more than seven times the gross value of the factory output of Waterloo. In 1941, the number of factory employees in Kitchener was nearly six times as great as in Waterloo, a supremacy largely due to concentration of large factories in Kitchener, such as for rubber, textiles, furniture and meat packing.

As a result of greater industrial expansion, the structure of Kitchener is more complex. The commercial core of Kitchener, including retail and wholesale stores lies on King Street. It is concentric in orientation. There are also some outlying retail shopping areas on both ends of the street and elsewhere, which are practically absent in Waterloo. A large compact industrial area is along and near the C.N.R. railroad. All around the city are many scattered factories, mostly along the railroads.

There are three better-class residential sections mainly on small hills: one, between the commercial core and the industrial section; two, east of the C.N.R. branch railway line. It is noteworthy that the southern one of the last two better residential areas has three semi-circular roads following contours of the hill, concentric to the point where a hospital stands, typical example of radial street pattern. All internal areas are mainly of third class residential sections. In Kitchener there is practically no fourth class residence area except a few houses of that class located near the above mentioned industrial area, despite its being highly industrialized in the whole region of the Grand River valley. Waterloo is less concentric in orientation and has a more or less distinct radial road setting. The commercial area is along the same street as that of Kitchener, which formed the only link between the two settlements in the early days. On the map is an outlying commercial area which is not composed of retail stores but represents the head office of an insurance company. The industrial area is, likewise, smaller, and not so well-differentiated from the commercial area as that of Kitchener. The residential sections mostly of third class are interspersed with three areas of better-class houses to the north, southwest and southeast of the center of the town.

FUNCTIONAL INDEPENDENCE AND INTERDEPENDENCE

Apparently, certain striking cultural features of one city are not found in the other—the county seat in Kitchener, the headquarter of insurance companies in Waterloo, for instance. More striking are differences in leading industries. Rubber factories form a dominant feature in the industrial landscape in Kitchener but there are none in Waterloo. Likewise, meat-packing is wholly concentrated in Kitchener. Leading industries in Waterloo are metal-working and breweries. In 1942 almost 40 per cent of factory employes

engaged in manufacture of machine tools. In normal times, farm implement industry predominates. But more significant is the fact that each has a commercial area, stores, hotels, theaters and so forth. Kitchener is an important freight connection of the C.N.R. while Waterloo is terminus of the Grand River Electric Railway. Also, both are road centers. Lastly, there is a large variety of industries common to both, such of furniture, buttons, gloves, textiles, beverages, shoes, paper products, flour and feed, etc.

As to functional interdependence, Waterloo depends more on Kitchener than vice versa. In both railway freight traffic and bus communication, Waterloo is tributary to Kitchener. Quite a few factories have their head offices or head plants in Kitchener. Indeed, there is much crossing of shoppers to the commercial core of Kitchener. The boundary is daily crossed also by factory workers. In this respect, Kitchener depends more on Waterloo. The functional interdependence of the two centers may be observed by the interurban street traffic. There is a street car commission running on the main street

FIGURE 4.—Commercial core of Kitchener, with its taller buildings and busier street scene, reveals the attributes of a larger urban center.

and a bus line giving and accepting transfers to and from the street railway. It is striking to observe that at noontime, there are crowds of workers of either Waterloo or Kitchener, going to their homes for luncheon. In conclusion, the functional interdependence of both outweighs in importance their independence, in analyzing the status of the twin communities.

THE MIDWAY ZONE OF CONTACT

That the twin cities are separated is obvious from study of the zone of con-

FIGURE 5.—The zone of contact of Kitchener with its industrial development, and Waterloo, along the right of way of the Canadian National Railway.

tact. A district that may be thought of as common to both centers, though politically included in Kitchener, lies between the main C.N.R. railway and the political boundary of both. Three sandy hills intervene in this zone. One lies directly on the main street, the artery of communication between the two, the other on the west side of the Grand River Electric Railway, and the third on the east side of the branch line of C.N.R. railway extending through Waterloo to Elmira. The first, that lies on the very zone of vital contact, has been used mainly for the sites of Kitchener-Waterloo Collegiate and Vocational School, the Kitchener-Waterloo Hospital and a cemetery, which serve both centers. The areas surrounding the public buildings and the cemetery are mainly third class residential sections mostly of factory workers. On the sandy hills just west of the Grand River Electric Railway is a recently developed

residential district which, politically, belongs to Kitchener but virtually is common to both. On the hills east of the branch line of C.N.R. is mainly an open land with a few houses scattered around.

THE FUTURE STATUS

From a geographical point of view, Waterloo is part of greater Kitchener. Under present conditions of communication it will remain so. The building of the C.N.R., as has been noted, was the main factor in favor of Kitchener, the reason why Kitchener has outgrown Waterloo so far, for both centers lie in the same physical environment and are settled by the people of same descent—German. But, though outlying sections of the two centers essentially overlap, their commercial cores will be separated as they are at the present; only phenomenal and totally unexpected growth could lead to coalescence, because at the northern end of the commercial core in Kitchener is an industrial area crossed by the main line of C.N.R. and in the zone of contact there are a cemetery, and public buildings—hospital, church and schools. It is not likely that any change will displace them for commercial expansion in the immediate future. Waterloo is a satellite of greater Kitchener, and must remain so for many years to come; but its commercial area will remain separate, serving local business.

ROLE OF PUEBLO INDIAN ECONOMY IN SANTA FE

Irene A. Moke

SANTA FE, situated on a piedmont plain in the northern part of the Rio Grande drainage area, is located about midway between Albuquerque and Taos. As the greater concentration of Rio Grande pueblos lies in this upper basin, the capital of New Mexico has numerous pueblo neighbors. Fifteen of the eighteen Indian villages in the Rio Grande basin are within a radius of seventy miles from Santa Fe (Map).

In 1610 when the city was founded, its relative centrality of location with regard to the Indian population was undoubtedly a directing factor in the choice of the site. Today, the locational factor which once was significant because of its strategic and administrative advantages has become important in its economic value to Santa Fe. In the twentieth century, and more particularly during the past two decades, the city has become a center of tourism in the Southwest. Its charm is compounded of many things, among them delightful summer climate, magnificent surrounding scenery, and historic background, to which must be added that indefinable quality which we term "flavor," or "personality," or "atmosphere." An essential and integral part of the distinctive atmosphere of Santa Fe is its pueblo setting and participation of the Pueblo Indians in its economic life. The Indian villages and the capital are economically related in three major ways, namely, (1) the city serves as a base of operations for routists who drive out to visit the pueblos, (2) during the yearly Fiesta at Santa Fe, Indian dances and markets are leading features of interest, and (3) the Indians make distinctive articles of handicraft which they sell in Santa Fe and add to the city's attraction for visitors.

Wartime restrictions on driving have temporarily curtailed use of Santa Fe as a base from which visits to the pueblos could be made. At present (1945) only those accessible by bus have numerous visitors. Under ordinary conditions, any one of the pueblos could be reached easily from Santa Fe and the return trip made in a single day or less. The Indian towns attract visitors because they portray a way of life which antedates Spanish settlement of the Southwest and because they are unique to the Southwest. Intrinsically, their attraction lies in the people themselves, distinctive pueblo architecture, hand-wrought articles offered for sale, and colorful ceremonies of the dances held at frequent intervals.

All pueblos contain fine examples of the Southwestern adobe style of building, but of them all Taos is the most renowned architecturally. It is the only example still occupied in the Rio Grande drainage basin of the many-storied, terraced, communal-house type of pueblo. The village is located in the productive irrigated valley of Taos creek, and farming has proved to be so satisfactory as a means of livelihood that handicraft has been neglected. People visit Taos for its architecture more than for any other reason.

Other Indian towns, less striking

architecturally, are noted more for their handicrafts. San Ildefonso and Santa Clara are leaders in fine pottery production, Santo Domingo in jewelry. Jémez and Tesuque produce novelty pottery types, brightly colored but not true ceramics, as the paints used are show-card colors applied after firing. Nevertheless, the Jémez and Tesuque ware has extensive sale among tourists. Tesuque may be visited easily in normal times, even by those who plan to remain in the capital for only part of a day, as it is but eight miles distant.

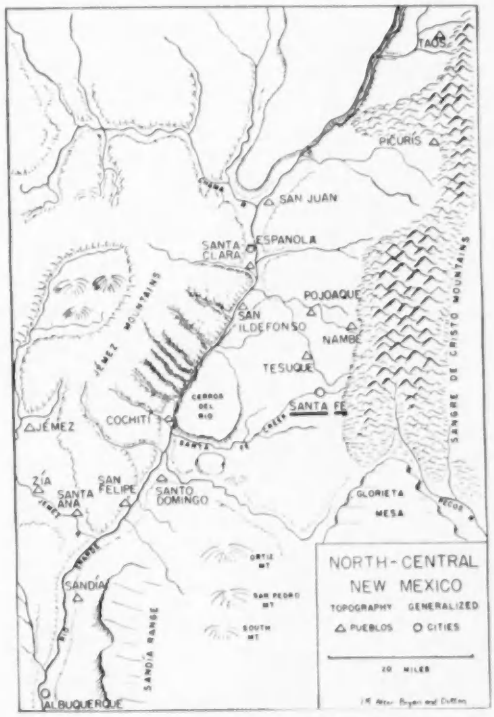

FIGURE 1.—North-Central New Mexico, including chiefly the upper Rio Grande watershed, indicating location of the principal cities and pueblos of the region, to which tourism has been diverted because of the Indian Culture.

All pueblos in the Rio Grande valley have special ceremonial events, chiefly dances in full panoply of headdresses, masks, feathers, and various other ornaments. The colorful pageantry in a setting of adobe attracts many visitors and students of Indian ways each year. The ceremonies relate to planting, to the ripening of plants and harvesting, to rainfall, to plant and animal life, and to hunting. Under the aegis of Catholicism there are dances dedicated to various saints, for the Indians have experienced little difficulty in assuming a veneer of Christianity over their pagan religion. The ritual remains much the same as it would in an Indian religious ceremony but the name is changed. In every month of the year a dance is held at one or more of the pueblos. Dances are most numerous, however, in July and January.

Santa Fe would entertain many visitors during the year even though it did not possess the advantage of being conveniently located with regard to the pueblos. It is undoubtedly true, however, that visitors interested in Indian ways stay longer in the city because it is a convenient center of operations from which to visit the Indian settlements.

There is one time of the year when tourists may see Indians from various pueblos and witness some of the dances without leaving Santa Fe. Every fall, around the first of September, an annual Fiesta is held. At that time the city is jammed with visitors, and the Pueblo Indians come into town with pottery, corn and seed necklaces, textiles, silver and mosaic jewelry, and other articles which they have made in anticipation of a good market. The *portal*, or covered gallery, of the Palace is lined with a double row of vendors, and between the rows, up and down, mill the buyers. A customary feature of the Fiesta is the presentation of various dances by Indians at the Museum of New Mexico or in the plaza. Santa Fe's hotels and auto courts are inadequate to handle the volume of business during the Fiesta, and it is

not unusual for visitors to spend a night or longer in their automobiles or in camp near the city.

Throughout the rest of the year, however, while the visitor to Santa Fe sees on the streets a few Indians in native dress, offering items of jewelry and pottery for sale, the chief commercial relationship between visitor and Indian is maintained through purchase of Indian handicraft in the shops. About five per cent of the retail establishments deal exclusively in Indian-made articles, and stores depend almost entirely on the tourist trade. Statistics are not available which would indicate the volume of business between pueblos and merchants. Part of the reason for the lack of available records may be the competitive nature of the business and therefore the unwillingness of merchants to part with their trade secrets. Furthermore, economic relations between pueblos and stores are partly on cash, and partly on barter basis, which would tend to confuse the records. Finally, the pueblos are not accustomed to keeping accounts, so that even were the Indians willing to divulge the information it would not be reliable.

While some of the articles handled come from Mexico, and some from the Zuñis, the Navajos, and the Hopis, the discussion of the handicrafts of these peoples and their marketing systems does not properly come within the scope of this paper. Most of the handicraft items originate with the Rio Grande Indians; some are made by Indians in workshops connected with the stores, and some are obtained from pueblos or from Pueblo Indians living in Santa Fe. Indian handicraft is sold also in the United States Indian School. Although some wares are brought to the school from the villages, many

FIGURE 2.—West group of residences in Taos Pueblo, northernmost of the section portrayed in Figure 1. All pueblos contain fine examples of Southwestern adobe buildings, but of them all, Taos is most renowned architecturally.

articles offered for sale there are wrought in the department of arts and crafts on the campus.

The various Rio Grande pueblos have developed certain specialties, so that a given town may be noted for one or more specific types of articles, and Indians from that town who go to school or who work in the city often continue to do the same kind of handicraft which they learned in their home village. The specialties of the different pueblos are listed herewith:

TYPES OF HANDICRAFT IN THE RIO GRANDE PUEBLOS*

Articles Wrought	*Pueblo*
Jewelry (mosaic and silver)	Santo Domingo
Pottery	San Ildefonso, Santa Clara, San Juan, Santo Domingo Zia, Cochití, Tesuque, Jémez
Drums	Cochití, Taos
Baskets	Jémez
Moccasins	Taos (beaded); Santo Domingo (plain)
Belts (cotton and wool)	Jémez, Nambé, Picuris, Isleta
Paintings	San Ildefonso, Taos, Cochití
Beaded Novelties	Cochití, Tesuque, Zia

*Prepared with the assistance of Miss Bertha Dutton, Museum of New Mexico, and Miss Mary Mitchell, United States Indian School at Santa Fe.

All articles are wrought by hand, from combinations of local and imported materials. Local materials include cottonwood logs for the drums, some of the leather and skins for moccasins and drum-tops, yucca and bear grass for baskets, and clay for pottery. Purchased materials are cotton and wool, silver, turquoise, leather soles, beads, and the show-card colors with which Tesuque and Jémez decorate much of their pottery. The silver used is imported from refineries in New York or in California, and comes in sheets, wires, and slugs. Turquoise is imported chiefly from Nevada mines. Bought in the rough, it is cut and polished in the Santa Fe shops, graded to size and quality, and sold by the pound. Pueblo Indians obtain silver and turquoise for their jewelry work from Santa Fe merchants.

Jewelry and pottery are the best-selling articles. Of the two, pottery is the more characteristic of a village-made article. All pueblo ceramic ware sold in Santa Fe was made in the pueblos, whereas a great deal of the pueblo-type silver and turquoise jewelry is made either in the town shops or in the homes of Indians who live in Santa Fe. There are some silversmiths in Santo Domingo, and a few in Tesuque, Cochití, and San Juan, but silversmithing is relatively unimportant in the Rio Grande towns. Nevertheless, the economic importance of the Rio Grande Indians in silver work is indicated by

FIGURE 3.—Ceremonial Indian dance in full costume at Santa Clara. The colorful pageantry in the adobe setting attracts hosts of tourists and visitors every month of the year, but dances are most numerous and distinctive in July and January.